THE PALYNOLOGY OF THE OHAI COALFIELD, SOUTHLAND

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ABSTRACT

The Upper Cretaceous Morley Coal Measures in the Ohai Coalfield are one of three non-marine formations constituting the Ohai Group. In the past, seam correlation has generally been carried out using lithological criteria, however due to dramatic thinning and splitting of seams, associated faulting, and abrupt facies changes uncertainties in coal seam correlation have frequently arisen. In order to minimize lithostratigraphic uncertainties Couper (1964) pioneered a palynological zonation which demonstrated the potential of palynology for coal seam correlation. However, Couper's early work has proved unreliable and is in need of further refinement.

Recent drillholes incorporating almost fully cored sequences of the Morley Formation have permitted further palynological examination of the coal measures. Nine drillholes were selected and 140 samples taken, at 10 metre intervals, for palynological analyses.

The Morley Coal Measures are unconformably overlain by the Beaumont Coal Measures. This important boundary, though difficult to detect lithologically, is readily defined on palynological grounds.

Biostratigraphic subdivision of the Morley Coal Measures was investigated by the application of three quantitative techniques. These entailed the construction and analysis of: (1) Standard pollen diagrams based on relative abundances of selected taxa and groups of taxa; (2) Pollen diagrams zoned by the numerical method of cluster analysis; (3) Ratios of selected taxa of recurrent and variably high frequency.

Technique (1), involving relative abundance patterns of key taxa and groups of taxa was successful in providing a basis for subdivision of the Morley Coal Measures into three pollen zones, two interzonal units and two unzoned units. The three pollen zones were, in stratigraphically descending order: The *Nothofagus kaitangata* acme zone, The SPPA assemblage zone, and the *Tricolpites reticulatus* acme zone.

Techniques (2) and (3) were, in all practicality, unproductive, although results suggested that, with refinement, cluster analysis could aid the zonation of pollen diagrams.

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CHAPTER 1

INTRODUCTION

1.1 LOCATION

The economically important Ohai Coalfield of Late Cretaceous - Early Tertiary age is situated some 80km northwest of Invercargill (Figure 1) where it lies within an east - west, fault bounded depression that separates the Takitimu and Longwood Mountain Ranges. The township of Ohai has a population of about 500 and is accessed by both state highway and rail connecting the Southland Plains to the Waiau Valley. The coalfield covers approximately 100 sq km. Ohai is mapped on the N.Z.G.S 1:250 000 series, sheet 24 of Invercargill; the N.Z.G.S 1:63 360 series, sheets S159 and S168; and on 1:16 042 sheets of Bowen (1964), N.Z.G.S Bulletin 51, Geology of Ohai Coalfield.

1.2 PREVIOUS GEOLOGICAL INVESTIGATIONS

The first geological account of the coalfield appears to have been that of Hector (1869) who briefly described the coal measures noting many of their characteristics. His observations were mainly of the Tertiary coals in which he recorded the resinous nature, the seam thickness variation, the ferruginous nodules in the mudstones, and the freshwater bivalve *Unio* (now *Velesunio huttoni*). He deduced that these beds rested unconformably upon fossiliferous Triassic sediments and also that they dipped beneath the overlying Tertiary marls and limestones. At that time Hector considered the coal measures to be probably correlative with those on the West Coast, Shag Point, and the Waikato.

Hutton (1872) applied the name Brown Coal Formation to the coal measures of the Ohai depression, regarding them as Lower or Middle Eocene. He also noted the variation in dip direction and seam thickness, and also observed that considerable erosion had occurred after the

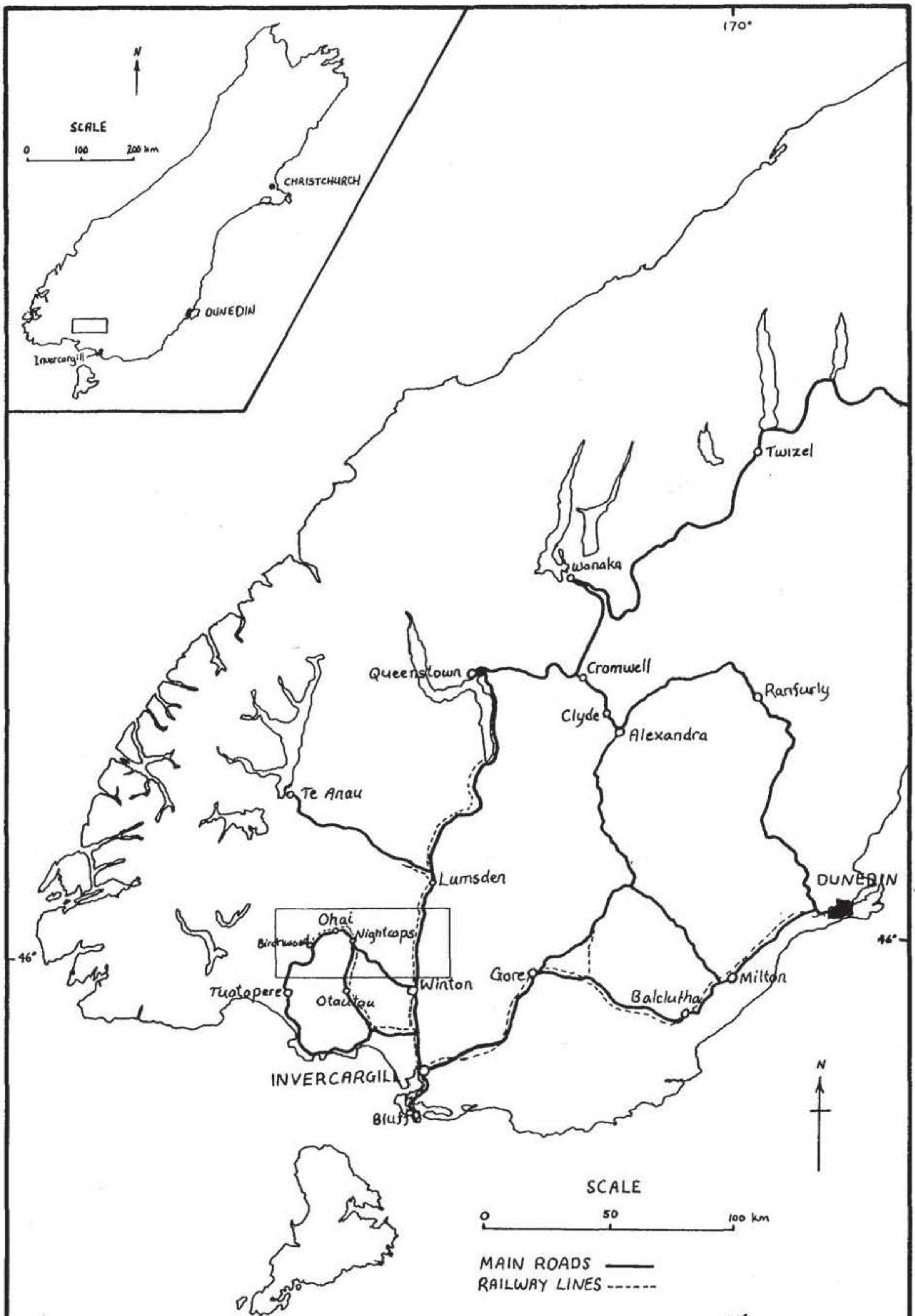


Figure 1 : Locality map showing Ohai Coalfield and main access routes.

deposition of the upper Mesozoic rocks.

Brief reports by Ongley (1917) and Morgan (1920) referred to the multiple seam nature of the coalfield, the lenticularity of seams and the disturbance of the field by faults. It was apparent from Ongley's map that both Upper Cretaceous and Tertiary coals were being mined although this was not realised at the time. Both reports indicated the need for further geological work in order to fully utilize the coalfield.

Park (1921) submitted the most complete of the early accounts and made an attempt at seam correlation. He recognised three seams; the "resin seam", the "main seam", and the stratigraphically lowest "thin seam". The latter two are now called the Morley No.2 seam and No.3 seam respectively (Bowen 1964). As is now apparent, Park's attempt at correlation was based on an oversimplified structural assessment. Many of his correlations were extended too far and, consequently, were generally incorrect.

Lillie from 1942 to 1945 (Lillie 1945, unpublished N.Z.G.S report) undertook the first detailed study of the Ohai Coalfield. In the course of his work he encountered many stratigraphic and structural complexities and, as a consequence, his attempts at correlation were limited and confined to small areas; in some places several alternative correlations were suggested. It is not clear what age Lillie assigned the coal measures. Initially, he recognised four main seams, assigning them a Cretaceous age, and a number of resin seams which he thought were Tertiary. At a later stage Lillie assigned all the coal measures to the Tertiary though suggested they might be Upper Cretaceous in age by comparison with the Kaitangata Coal Measures. Irrespective of this confusion the Cretaceous/Tertiary unconformity within the coal measures remained unrecognised.

On the recommendations of Lillie (1945) an extensive drilling program was initiated. This programme, which by 1953 was largely completed, was accompanied by a major geological survey undertaken by F.E Bowen (Bowen 1964). This survey resulted in a reinterpretation of the stratigraphy, structure, and seam correlation of the Ohai coalfield.

Bowen (in Couper 1953) recognised that the coal measures of the Ohai/Nightcaps district could be divided into two groups which were separated by a major unconformity. The older group was subdivided into the Lower and Middle Ohai Groups while the younger group was called the Upper Ohai Group.

At that time R.A Couper (in Suggate and Couper 1952, Couper 1953) constructed a palynological zonation based on material examined from various seams established by Bowen. This scheme supported Bowen's correlations over most of the area but lead to a reinterpretation of an area in the northeast of the district. Couper assigned to the Lower and Middle Ohai Groups an Upper Cretaceous age (Haumurian and possibly Piripauan) and to the Upper Ohai Group a Middle to Late Eocene age. He noted that the Lower and Middle Groups were similar, with discrimination between them based on relative abundance rather than distinctiveness of species. The Upper and Middle Groups, however, Couper distinguished on major floral differences. The almost complete absence of conifer and proteaceous taxa, characteristic of the Lower and middle Groups, was a conspicuous feature of the Upper Group.

Bowen's study of the coalfield culminated with the publication of his "Geology of the Ohai Coalfield" bulletin in 1964. His final refinement of subdivisions are set out in Table 1.

Sykes (1985) carried out an M.Sc study on the Ohai Coalfield examining the paleoenvironmental and tectonic controls on the coal measure characteristics. He introduced a number of fundamentally new concepts for depositional models with respect to coal exploration and mine development and employed the use of palynology in a number of cases to distinguish between Beaumont and Morley formations.

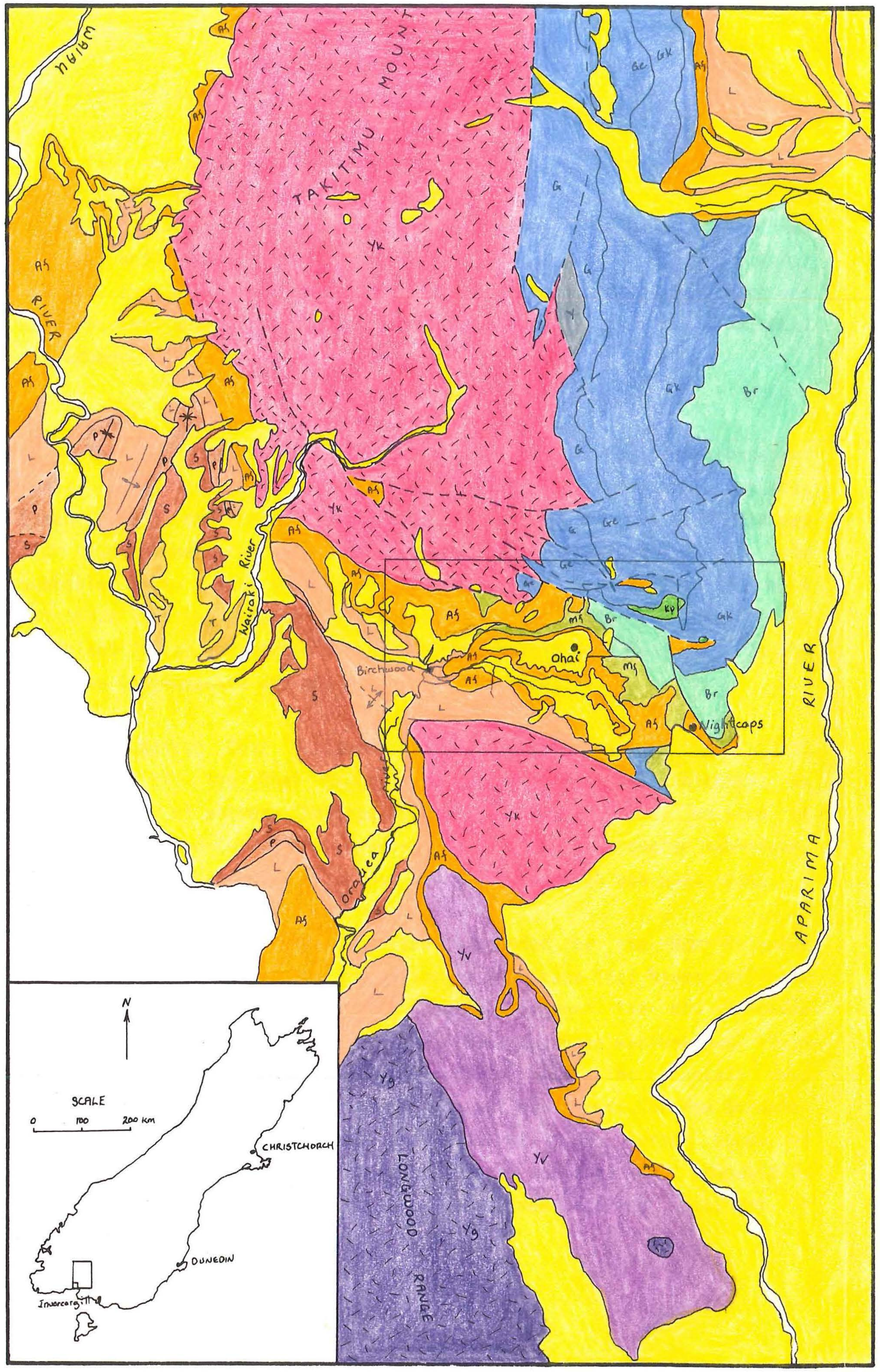
In addition to these relatively general geological accounts (with the exception of Sykes 1985) other studies of more specialised nature have been carried out. These include Gravity surveys, Seismic surveys, coal geochemical and mineralogical studies, and a number of palynological investigations.

Bowen, in Couper 1953	Bowen 1964		
			Whaingaroan
		Orauea mudstone	
Upper Ohai Group	Nightcaps Group		
		Beaumont Coal Measures	
			Bortonian
		unconformity	
Middle Ohai Group		Morley Coal Measures	Haumurian
	Ohai Group	New Brighton conglomerate	
Lower Ohai Group			
		Wairio Coal Measures	Piripauan
unconformity		unconformity	
			Triassic
Basement		Basement	
			Carboniferous

Table 1 : Stratigraphy of the Ohai Coalfield (after Bowen 1964).

1.3 GEOLOGICAL SETTING OF THE COALFIELD

The region around the coalfield is divisible into three north-south trending belts which, from west to east, comprise: the Tertiary sediments of the Waiau Basin, the Permo-Carboniferous volcanics and intrusives of the Takitimu-Longwood Ranges, and the Triassic sediments forming part of the southwestern limb of the Southland Syncline (Figure 2). The Ohai Basin is a fault-bounded sedimentary basin lying within the Takitimu Volcanics and is a conspicuous feature because of its east-west trend and Cretaceous sediment content. At its northeastern boundary the sequence either laps unconformably onto, or is in fault contact with Triassic sediments. To the northwest the nature of the contact is somewhat uncertain. Wood (1966) and Mutch (1964) on their maps show the contact as being predominantly sedimentary. However Bowen (1964) and Sykes (1985) consider the contact to be faulted. The southern margin of the basin is clearly fault bounded against the Takitimu Volcanics of the Woodlaw Range. Recent work with gravity anomaly data (Woodward and Kicinski 1983; in Sykes 1985) suggest that the major fault along this contact, the Twinlaw Fault, has a major dip-slip component (dipping to the south).



LEGEND

LITHOLOGY		AGE
	Stream alluvium, estuary and swamp deposits (weathered), outwash gravels, till and moranic deposits, marine and associated river gravels, very weathered gravels.	Holocene Pleistocene
T	Marine siltstone and mudstone	Miocene
S	Shelly sandstone, limestone, mudstone, sandymudstone, interbedded geosynclinal sandstone and mudstone, glauconitic sandstone.	
P	Thick geosynclinal mudstones and sandstones; limestone.	
L	Thick interbedded calcareous sandstone and limestone, or grey massive mudstone, all geosynclinal. Quartz sands. Orauea mudstone at Ohai.	Oligocene
Af	Quartzo feldspathic sandstone and mudstone with resinous sub-bituminous coal seams; at Ohai comprises Beaumont Coal Measures.	Eocene
Mf	Quartzo feldspathic sandstone and mudstone, conglomerate with sub-bituminous to high volitile bituminous coal seams: the Ohai Group.	Cretaceous
Kp	Augite porphyrite, small plugs and dikes.	Jurassic to Triassic
Bm	Fossiliferous sandstone, dark siltstone, feldspath grit, zeolitised tuff, intraformational breccia, conglomerate.	Triassic
Br	Fossiliferous tuffaceous sandstone and siltstone, zeolitised vitric and other tuffs and tuffaceous breccia, conglomerate.	
Gk	Fossiliferous tuffaceous sandstone, siltstone, mudstone, other tuffs.	
Ge	On southwest limb Southland syncline; sandstone and dark fossiliferous mudstone	
G	Coarse tuffaceous sandstone and basal conglomerate.	
Yp	Productus Creek Group	Permian
Yk	Takitimu Volcanics	Permian to Carboniferous
Yv	Undifferentiated greywacke, tuff, and volcanics	
Yg	Longwood Intrusives	

GEOLOGICAL SYMBOLS

Contact
Fault
Concealed
Folds
Anticline
Syncline
Concealed fold

SCALE

1 : 250,000 (Approx 4 miles to 1 inch)

0 5 10 15 km

Figure 2 : Regional geological setting of the Ohai Coalfield. After Wood (1966) (coalfield is outlined).

1.4 STRATIGRAPHY

The stratigraphic terminology applied in this thesis follows Bowen (1964) (Table 1). Two groups are recognised:

(1) The lower Ohai Group of Upper Cretaceous (Piripauan-Haumaurian) age, and

(2) the Nightcaps Group of mid Eocene to lower Oligocene age (Runangan-Whaingaroan). This group unconformably overlies the Ohai Group.

1.4.1 The Ohai Group

The Ohai Group rests unconformably on pre-Cretaceous basement rocks. Latest drillhole data indicate a maximum thickness of 330 metres. Bowen (1964) considered it likely that the original sediment pile was much thicker than the maximum thickness now preserved. It is also probable that these sediments were deposited over an area much more extensive than the present confines of the coalfield. The Ohai Group comprises three non-marine formations; the Wairio Coal Measures, the New Brighton Conglomerate and the Morley Coal Measures.

The Wairio Coal Measures are, stratigraphically, the oldest formation of the Ohai Group. The maximum recorded thickness is approximately 51 metres. The type section, found at the junction of Morley Stream and Coal Creek, consists of conglomerate, coarse sandstone, shale and thin (generally less than 1.3 m thick), high ash coal seams.

The Wairio Coal Measures are succeeded by the New Brighton Conglomerate. Prior to the completion of the State Coal Mines Drillhole 343 in July 1984 the nature of the contact between the New Brighton Conglomerate and the underlying Wairio Coal Measures was unknown; it is now known to be unconformable. Prior to this the contact was indeterminable as no outcrop of the contact was known. The New Brighton Conglomerate comprises dominantly conglomerate with lesser bands of sandstone (usually coarse), mudstone, shale and coal (most commonly in the upper 40 metres of the formation. The maximum recorded thickness is approximately 110-120 metres.

The Morley Coal Measures are the youngest Formation within the Ohai Group and are of greatest economic importance. The contact between the Morley Coal Measures and the underlying New Brighton Conglomerate appears to be conformable over much of the coalfield, however Bowen (1964) suggested it may be unconformable in some areas near Nightcaps township. The maximum thickness of this formation is somewhat uncertain due mainly to the difficulty in detecting the unconformity separating the Ohai Group as a whole from the overlying Nightcaps Group. Bowen (1964) suggested a thickness for the Morley Coal Measures of some 170 metres however Sykes (1985) indicated 217 metres; Sykes' estimate is considered probably more accurate as palynological age control was used. It is almost certain, though, that the present thickness of the formation does not represent the maximum original thickness. Bowen (1964) suggested that during deposition of the coal measures, folding and faulting, accompanied by erosion, resulted in numerous breaks in the sequence and abrupt facies changes. He also noted that increasing thicknesses between the bases of some of the coal seams indicated thickening of the sediments towards the present synclinal areas. These movements culminated in the period of widespread erosion prior to the deposition of the Nightcaps Group.

Lithologies within the Morley Coal Measures range from clays through to boulder conglomerate, with carbonaceous muds, siltstones and sandstones being particularly prominent in areas adjacent to coal seams. Six coal horizons of economic importance are recognised. From the oldest to youngest they are: No.3 seam, Couper Seam, Morley No.2 seam, Linton Main Seam/Morley No.1½ seam, Morley No.1 seam and Star seam. Referral to these horizons as discrete "seams" is misleading as, almost certainly there is splitting and thinning of seams in stratigraphically adjacent parts of the coalfield. Coal seams vary significantly in thickness over the coalfield up to a maximum of about 30 metres (Figure 13, in pocket). All lithologies are irregularly repeated throughout the formation and, with the exception of some coal seams and conglomerates, no single lithology can be traced over any great distance with certainty. Subdivision of the sequence into lithostratigraphic members has thus far proved impossible.

A biostratigraphic zonation was established by Couper (1964) who divided the Morley Coal Measures into three zones. The lowermost was the *Podocarpidites cf. ellipticus* Zone (Couper and Morley No.3 seams), followed by the *Dacrydiumites* Zone (informally called *Phyllocladidites* zone by Pocknall 1984)(No.1, No.1½, Linton Main and No.2 seams), followed by the uppermost *Podocarpidites marwickii* Zone (Star Seam). Recent palynological work, however, has revealed inconsistencies in Coupers pioneering scheme. Pocknall (1984) considered the application of Coupers biostratigraphical framework problematical with difficulties arising through inconsistent assemblages in the dominant coal forming vegetation. Sykes (1985) also noted inconsistencies in the scheme.

1.4.2 The Nightcaps Group

The Nightcaps Group is divided into two formations; the lower Beaumont Coal Measures (Bortonian - Runangan) and, conformably overlying this, the esturine/marine Orauea Mudstone (Runangan - Whaingaroan). The Nightcaps Group rests unconformably upon either Ohai Group rocks or pre-Cretaceous basement rocks. Sediments of this group are widespread, being found within the Waiau basin and lapping onto the northeastern limb and hinge region of the Southland Syncline.

The Beaumont Coal Measures have a maximum known thickness of 244 metres (Sykes 1985) and are composed of mudstones, siltstones, sandstones, fine conglomerate and thin (less than 6 metre) lenticular coal seams of generally poor quality. Coal of this formation is characteristically very resinous. As in the Morley Coal Measures lithologies are irregularly repeated and no single lithology persists for any great lateral extent making lithostratigraphic subdivision impractical. Couper (1964) established a biostratigraphic zonation involving two zones. The distinctiveness of the Eocene palynomorphs occurring in this unit makes differentiation from the underlying Morley Formation a routine procedure.

1.5 STRUCTURE

The northwest trending folds in the Ohai Coalfield follow a

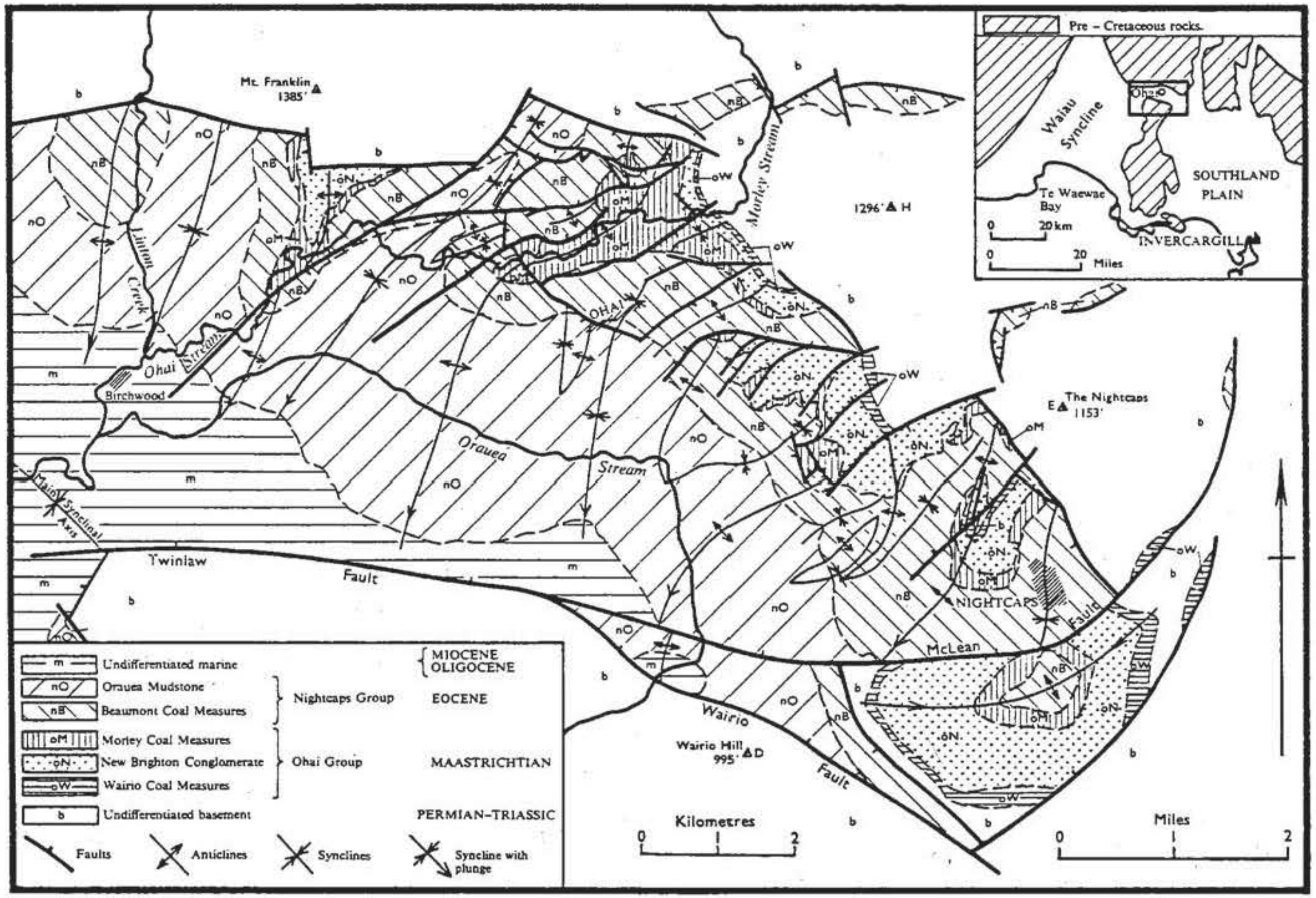


Figure 3 : Geological map of Ohai Coalfield (Suggate 1978).

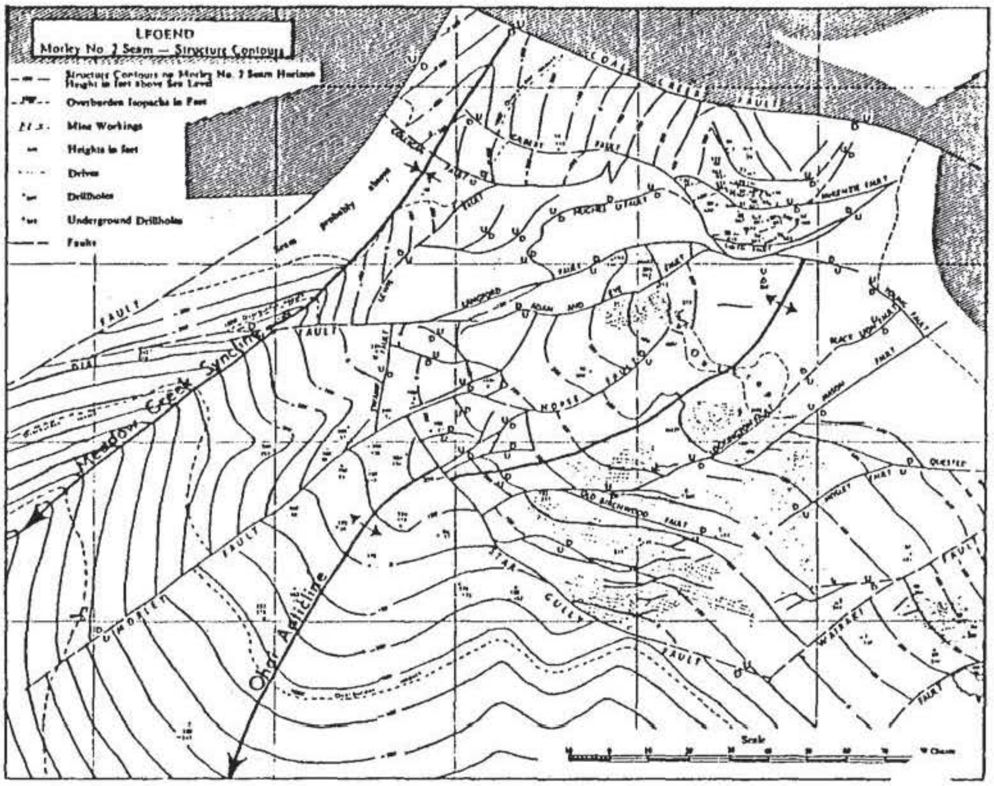


Figure 4a : Structure contours on the Morley No.2 Seam horizon (from Bowen, 1964).

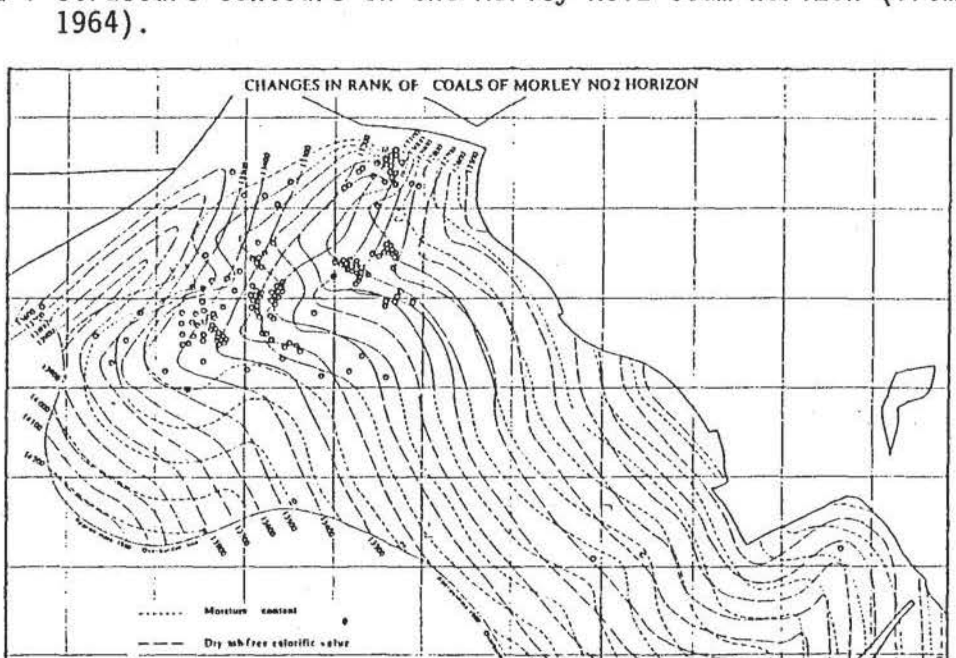


Figure 4b : Equal-calorific value and equal-moisture lines for the Morley No.2 seam horizon (from Bowen 1964).

dominant Cretaceous structural trend. The coal measure sediments form the northeastern limb of a major syncline, the axis of which lies 2 km southwest of Birchwood (Figure 3). This limb is itself folded into southwest and south plunging secondary anticlines and synclines. One such anticline - the Ohai Anticline - has resulted in the present coalworkings being brought close to the surface. The regional dip of the Cretaceous and Tertiary rocks is to the southwest. Coal rank studies (Bowen 1964) indicate rank variation broadly parallels the dominant structural features (figure 4). Major faults generally parallel the northeast trend of folding, however minor faults appear randomly orientated. Fault attitude is near vertical with sinuous traces.

Faulting and folding was believed by Bowen (1964) to be contemporaneous with sedimentation. Evidence for this is seen in sequence breaks, abrupt facies changes, and considerable variation in sediment thickness. These events culminated at the end of the Cretaceous in a period of extensive erosion resulting in a widespread surface of unconformity. Deformation of the Beaumont Coal Measure sequence has been less severe.

1.6 OBJECTIVES

In any coalfield successful exploitation of coal reserves hinges on a sound understanding of the geology of the area. At Ohai the basic structure of the field is essentially understood, however, despite almost 120 years of geological investigations (see section 1.2) the reliability of subsurface correlations of coal seams and associated sediments is still in doubt, for a variety of reasons. These include:

(a) Poor surface outcrop of members. Much of the original stratigraphy interpreted from early drillhole data is of doubtful accuracy.

(b) Lack of distinctive marker horizons.

(c) Lateral facies changes and associated periods of erosion.

(d) Uncertainties in correlating both lithological and geophysical characteristics of individual members between drillholes.

(e) The difficulty in detecting the boundary between the Beaumont and

Morley Formations.

(f) Uncertainties involving the number of, and nature and extent of faults.

The present study addresses the problem of geological correlation at Ohai by employing a palynological approach, that utilizes the fossil spores and pollen abundantly preserved and distributed in the sediments. As with all constituents of the fossil record, there are unmistakable changes in spore and pollen composition with time. Such changes form the basis for palynostratigraphical zonations that are now routinely used worldwide in petroleum exploration and the like.

The main objectives of the study were as follows:

(1) To revise the palynological based biostratigraphy pioneered by Couper (1964).

(2) To establish a precise subdivision of the Morley Coal Measures that would allow improved coal seam correlation.

(3) To accurately delineate the Beaumont/Morley boundary in the selected drillholes.

CHAPTER 2

METHODS

2.1 SAMPLING

At Ohai, sample availability is dictated largely by drilling method. Many holes were open-hole drilled until a coal horizon or pre-determined depth was reached, at which stage coring commenced, often only for the duration of the coal seam. Open hole cuttings were unsuitable for palynological analysis due to the high contamination risk and uncertainty as to the depth from which the cuttings were derived. Holes where the Morley Formation was fully cored were favoured as this enabled sampling at regular intervals throughout the whole stratigraphic section. Nine holes were selected for analysis in this thesis, they were: drillhole 387, 336, 343, 347, 364, 335, 382, 384 and 375 (for drillhole location see Figure 5).

Non carbonaceous to slightly carbonaceous lithologies proved relatively unproductive and consequently were avoided. Coal samples also yielded poor palynomorph assemblages and were avoided, however, they have been found by other workers to yield good assemblages (Raine pers com, Raymond 1985, and others). This suggests the processing techniques employed in this study were probably at fault. Sampling in general was confined to dark carbonaceous mudstones and coaly mudstones where possible, which yielded good to excellent palynomorph assemblages. Coarse grained lithologies proved to be almost always barren. In order to include a satisfactory number of drillholes in the project the sample interval was based on 10 metre increments. This was increased or decreased depending on lithology and core availibility. Sample locations can be seen in Figure 13 (in pocket).

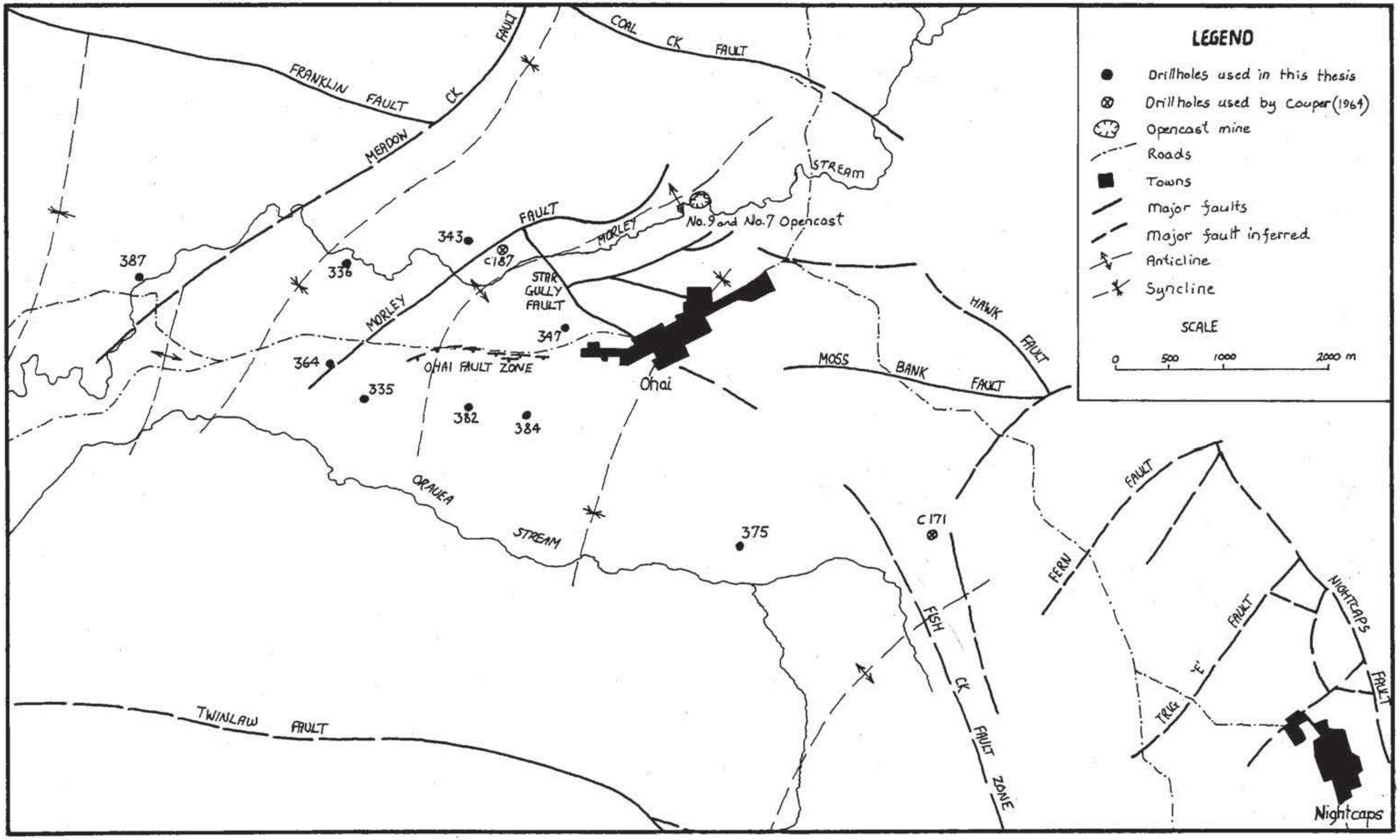


Figure 5 : Location of drillholes used in this thesis and by Couper (1964), also shows main structural features of the coalfield (after Bowen 1964).

Drillcore was held in the Coal Corporation Core shed at Ohai. Samples were collected from core which was contained in p.v.c tube halves wrapped in plastic. Each sample consisted of a 6 cm length half section of core, obtained by hammer and cold chisel and sealed in plastic bags. Only a half section of core was taken so as to preserve the continuity of the drillcore.

2.2 CHEMICAL HAZARDS

Many of the chemical reagents used in palynology are extremely dangerous; in addition hazardous products can be formed as by-products during processing. Efficient fume cupboard ventilation is imperative. Protective clothing was worn at all times in the laboratory, however, extra precautions were taken when working with Hydrofluoric Acid and the highly corrosive chemicals Nitric Acid, Zinc Bromide solution and Ammonium Hydroxide. All processing was carried out in fume cupboards.

2.3 PROCESSING

Crushing:

In order to eliminate contamination, the sample used for crushing was obtained by carefully chipping away the outer surface of the core leaving completely fresh material exposed. An airgun was used for chipping, the "bit" of which was flamed after each sample. The fresh sample was placed in a thick polythene bag and crushed to chips (approximately 0.5 - 2.0 mm dia) using a hammer. It was then divided into two fractions; one for storing away and the other for continued processing.

Hydrofluoric Acid Maceration:

Approximately 35 gms of sample - more was used if the sample was pale colored and had a low carbonaceous content - was put in a 250 ml Teflon beaker, covered with concentrated Hydrofluoric Acid (HF) and left to soak for 2 - 5 days. Reaction time varied, dependent on the siliceous content of the sample.

Washing:

After HF maceration, the residue was centrifuged in polypropylene tubes at 2000 r.p.m for 5 minutes and decanted. The remaining organic residue and HF was thoroughly washed in hot concentrated Hydrochloric acid (HCl) and again centrifuged at 2000 r.p.m for 5 minutes before decanting. The washing process was repeated using hot 10% HCl until all traces of HF were removed.

Oxidation:

15 - 30 mls of concentrated Nitric acid (HNO_3) and 50 - 150 mg of Potassium Chlorate crystals ($KClO_3$) were used to oxidise the organic residue. If the $KClO_3$ failed to produce a reaction, 50 - 100 gm of Chromium Trioxide crystals (CrO_3) were added. Reaction times (1 - 60 mins) and oxidant concentrations were varied depending on organic content. The oxidation was terminated by neutralizing with 5% Ammonium Hydroxide (NH_4OH) and washing with distilled water. Any detrimental effect of oxidation on palynomorph preservation was not investigated. Upon inspection of mounted samples differences in preservation were evident, however without further investigation it was difficult to establish whether the preservation differences are a result of taphonomic effects or processing procedures. No samples were acetolized as: **(a)** the oxidation already carried out gave satisfactory results and **(b)** the negative aspects were undesirable; that is, acetolisis tendes to remove naturally inherited color and induces inflation and distortion in palynomorphs.

Heavy Liquid Separation:

Excessive mineral content was removed using Zinc Bromide solution (S.G = 2.00).

Filtration:

Samples were checked by water mount for coarse material (usually unoxidised organic clumps) larger than approximately 240 µm diameter. Removal of coarse fraction was achieved with good results by carefully washing the residue through a 240 µm mesh with ethanol then centrifuging and decanting. The mesh was flamed after each sample. This method was both quick and efficient.

<u>Light Oxidation:</u>

At this stage the samples were checked and if necessary reoxidised as outlined above. The majority of samples were given a "light oxidation" using "Janola" (3% Sodium hypochlorate) for 10 to 60 seconds, excellent results were obtained. This last process also had the effect of removing fine unoxidised material. The residue was then divided and 2 ml transferred to 10 ml disposable tubes for short centrifuging (this was the maximum amount for practical purposes). The remainder was transferred to small glass specimen tubes with plastic screw tops for storage.

<u>Short Centrifuging:</u>

A series of short centrifuging - 2000 r.p.m over 30 seconds - 5 to 15 in number were performed in order to remove any remaining fine material. The process was repeated until the supernant became clear.

<u>Slide preparation:</u>

All slides were mounted in glycerine jelly and ringed with fingernail polish. Two slides - one stained with safranin, the other unstained - were prepared for each sample. Additional slides were made for samples with meagre assemblages. All slides were numbered with initially a laboratory code and later a University of Canterbury Palynology (U.C.P) number.

2.4 PALYNOMORPH IDENTIFICATION AND LABELLING

All slides were examined under a Zeiss photomicroscope 3 (Number Geol 844) housed in the Geology Department, University of Canterbury. Ilford Pan F 35mm film (50 ASA) was used for all photomicrographs. An ASA setting on the photomicroscope of $33^{1}/_{3}$ ASA produced the most consistent and well exposed photomicrographs; this setting was used through out the photographic procedure.

An examination of one drillhole was carried out in order to establish a basic assemblage suite. Obviously not all taxa occurring in the formation would necessarily be found in only one drillhole. In this drillhole every different palynomorph encountered was photographed, labelled, and morphologically measured and described. Identification at this stage was attempted but not pursued. A photographic album was constructed with palynomorphs arranged in groups according to morphology. Eight groups were distinguished: Saccate, Tricolpate, Tricolporate, Polyorate, Polycolpate, Monosulcate, Triorate, and an all encompassing group for Spores. As more samples were examined the groups were expanded and refined with formal names attached where applicable. When no formal name could be positively used a simple numbering system was incorporated. This system proved reliable and allowed undescribed taxa to be treated in the same way during counting as the described taxa.

Photographs of palynomorphs were mounted on cards (Figure 6) which listed the sample number from which the photographs were taken, the photographic referral number, morphologic measurements, and the name, age and author where applicable. Stage coordinates were also listed.

Taxonomy was carried out in a meticulous fashion with careful measurement and description of exine, overall size, sculptural elements, and other features. Comparison was mainly from New Zealand and Australian literature. On completion of taxonomy 125 different taxa were identified, of these, many were rare and undescribed. During counting the maximum number of different taxa recognised in any one hole was 82.

2.5 ANALYTICAL PROCEDURE

Counting began after the palynomorph identification procedure had been completed. As many as four slides were counted for samples low in palynomorph numbers. Samples rich in palynomorphs were counted on one or two slides. A 250 count was made for each sample. There is little agreement among palynologists concerning the numbers of spores or pollen grains that should be counted to ensure that the recorded assemblage is reasonably representative of the sample. Various workers have advocated counts ranging from 150 to 1000 grains. Barkley (1934) maintains that there is no advantage in counting more than 200 grains per slide but Dimbleby (1957) has demonstrated graphically that the rate of increase of species recorded declines rapidly after 250 has been counted, and that

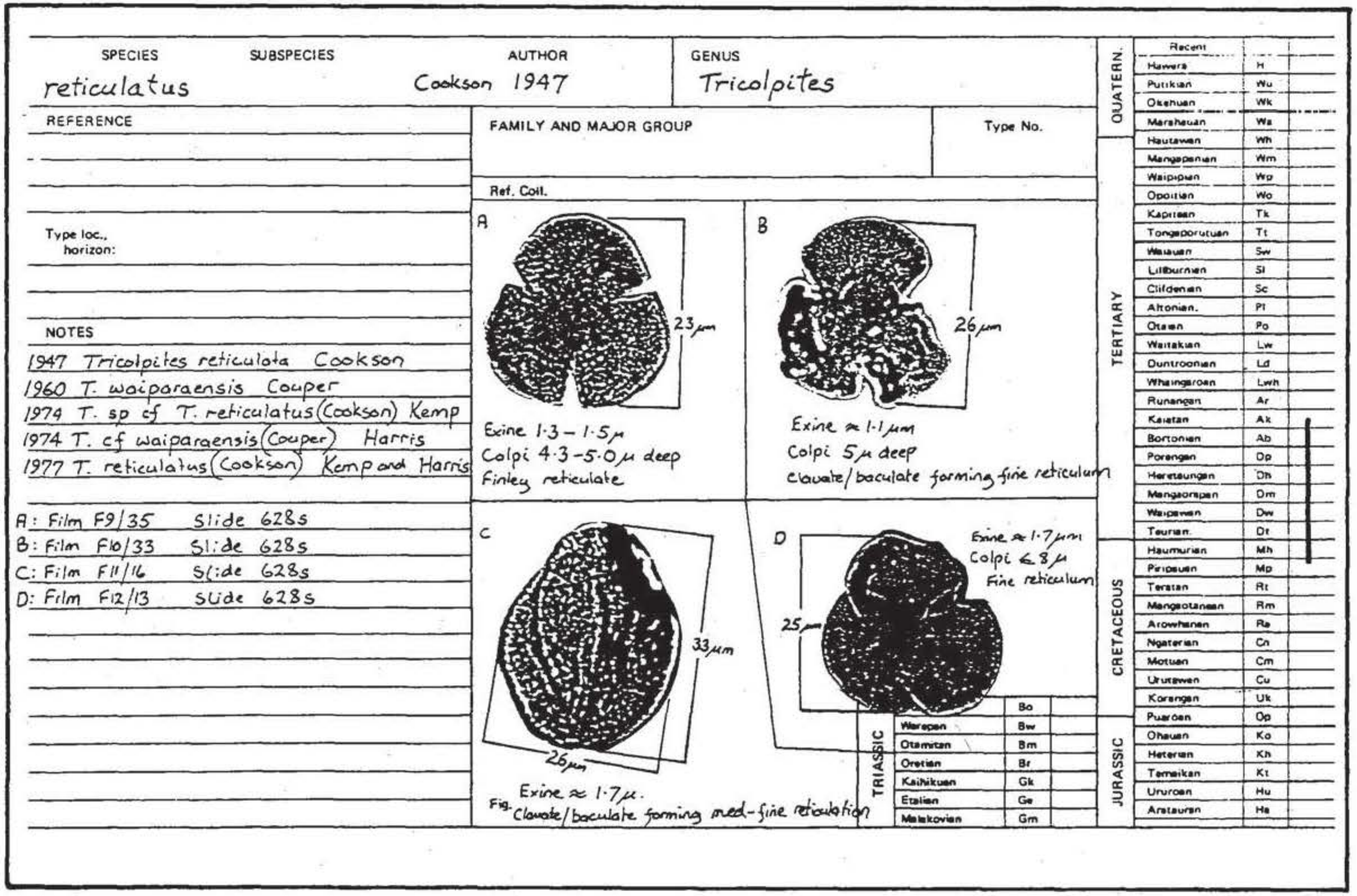


Figure 6 : Informal classification card used in palynomorph counting and identification.

all species which have a final percentage of one or more are represented within the first 250 grains. For a full discussion on this problem see Smith and Butterworth (1967). The NZ Geological Survey normally use a 200 count as they consider it gives a good approximation of the palynomorph assemblage while being a sufficiently low enough number to allow samples to be counted in a reasonable time. The 250 count in this project was chosen with these views in mind.

In all cases the slides were systematically traversed with overlapping fields of view to ensure full coverage. This ensured a random count and eliminated any distribution effects of palynomorphs under the coverslip. When the 250 count was reached the systematic coverage was continued until the entire slide had been scanned in order to pick up any new grains missed during the 250 count. All raw data and percentage data are listed in the appendices.

CHAPTER 3

EVALUATION OF COUPER'S SCHEME

3.1 INTRODUCTION

Couper (1964) pioneered a palynological-based biostratigraphic zonation scheme aimed at achieving broad correlation of coal seams in both the Beaumont Coal Measures of the Nightcaps Group, and the Morley Coal Measures, New Brighton Conglomerate, and Wairio Coal Measures of the Ohai Group (Table 1). Of particular relevance to the present study was Couper's approach to biostratigraphic palynology within the Morley sequence, the only coal bearing unit of economic significance.

The two analytical methods used by Couper were:

(a) correlation by spores and pollen grains with restricted ranges. This method was found to be useful in distinguishing between the Beaumont and Morley Coal Measures - the Beaumont being of significantly younger age.

(b) correlation by differences in the relative abundances of species, genera, or other broader taxonomic groupings of pollen and spores.

This latter method, utilizing selected species of conifer and beech pollen, permitted detailed biostratigraphic subdivision of both the Beaumont Coal Measures and all formations within the Ohai Group. Three zones were established in the Morley Coal Measures.

In his investigations Couper chose to ignore all spores and concentrate his efforts on selected anemophilous taxa. This he did in the light of earlier unpublished work (Harris and Couper, cited Couper 1964) which indicated that spores and pollen grains of certain bog and swamp plants such as *Sphagnum*, *Gleichenia*, *Typha*, and *Cyperacea* can vary considerably in their relative abundance over small lateral distances whilst, in the same samples, the relative abundances of wind-borne pollen grains such as conifers and beeches (*Nothofagus*) were remarkably uniform.

3.2 OUTLINE OF COUPER'S (1964) ZONATION

Throughout the Ohai Group there is a profusion of *Phyllocladidites mawsonii*. Couper used this conifer species as the base for comparison and statistical treatment of data by expressing other key species as a percentage of the total number of *P. mawsonii* in each sample. The key species so used by Couper in his Morley zonation were *Podocarpidites cf. ellipticus* (Cookson) and *Podocarpidites marwickii* (Couper). Couper's three zones, outlined below, were based on ratios of these key taxa with

ZONE	ZONAL CRITERIA
P. marwickii (upper part of Morley Coal Measures)	Ratio P. cf. ellipticus to P. marwickii less than 1
Transition zone	Ratio P. cf. ellipticus to P. marwickii between 1 and 1.2
P. mawsonii (middle part of Morley Coal Measures)	Ratio P. cf. ellipticus to P. marwickii greater than 2; P. cl. ellipticus plus P. marwickii less than 50% of P. mawsonii (expressed as percentages of P. mawsonii)
Transition zone	Ratio P. cf. ellipticus to P. marwickii greater than 1.2; P. cf. ellipticus plus P. marwickii between 50% and 55% of P. mawsonii (expressed as percentages of P. mawsonii)
P. cf. ellipticus (lower part of Morley Coal Measures)	Ratio P. cf. ellipticus to P. marwickii greater than 1.2; P. cf. ellipticus plus P. marwickii more than 55% P. mawsonii (expressed as percentages of P. mawsonii)

Table 2 : The zonal scheme established by Couper (1964) for the Morley Coal Measures.

certain empirically selected ratios defining zone boundaries. During the initial stages of his study Couper based the zones on sequences from drillholes S168/d165 and S168/d171. However, in d165 he found that a large number of samples yielded incompatible results - floras were suggesting zones that were stratigraphically impossible or at least opposed to stratigraphic indications. Couper suggested this was because the drillhole passed through the Morley Fault Zone, the sequence being consequently disrupted. As a result the zonation based on these sequences was abandoned and the zones redefined. The new sequence was established using samples from S168/d187, S168/d171, and opencast pits No.7 and No.9. The three zones and transition zones are presented in Table 2.

In S168/d187 drilling to a depth of 128 metres failed to reach the base of the Morley sequence: only the upper (*P. marwickii*) and middle (*P. mawsonii*) zones were determined in this hole. S168/d171 reached a total depth of 210 metres, penetrating the Beaumont, Morley, New Brighton, and Wairio Formations. Only the lower *P. cf. ellipticus* zone of the Morley sequence was determined in this hole. Samples from the No.7 and No.9 opencast pits were used to define the sequence from the *P. mawsonii* zone to the *P. cf. ellipticus* zone. 15 samples were used in distinguishing the *P. marwickii* zone, 37 in distinguishing the *P. mawsonii* zone, and 27 in distinguishing the *P. cf. ellipticus* zone. Couper acknowledged that his zonation would probably require revision with increasing knowledge of the flora. Table 3 shows the six main seams and the palynological zones to which they were assigned by Couper.

SEAM	Floral Zone
Star	Podocarpidites marwickii
Morley No. 1 Linton Main Morley No. 2	Phyllocladidites mawsonii
Couper Morley No. 3	Podocarpidites cf. ellipticus

Table 3 : The six main coal seams in the Ohai Coalfield and the palynological zones to which they were assigned by Couper (1964).

The sequence of coal seams presented in Table 2 is a composite and nowhere in the coalfield have all the seams been found, or recognized, in

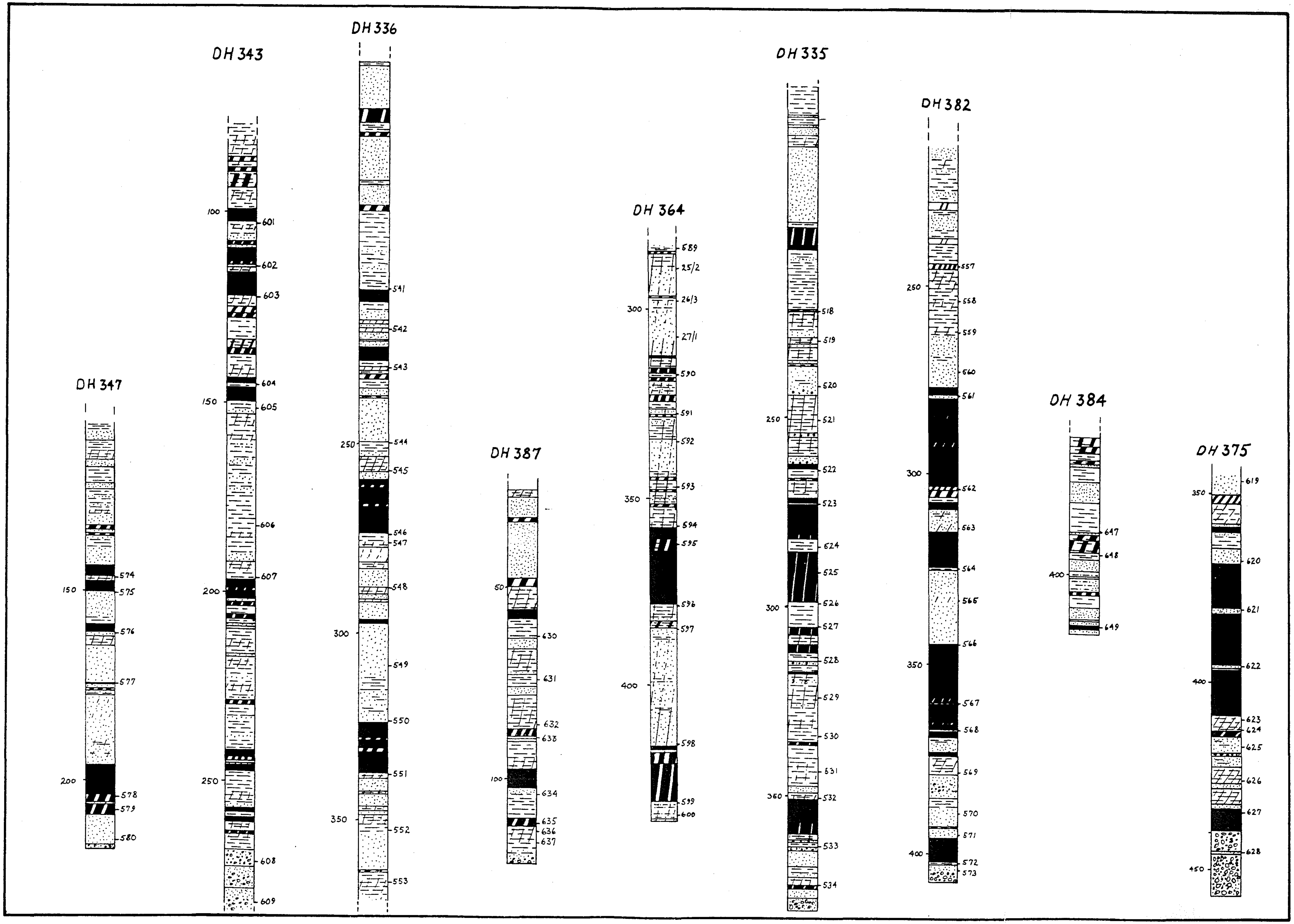


Figure 7 : Drillhole logs showing thickness variation in coal seams and intervening lithologies.

a single section. As observed by Bowen (1964) the intervals between coal seams vary considerably in thickness (Figure 7). He noted for example that the Star and Morley No. 3 seams, in places almost certainly consist of more than one seam. Bowen recognised the Couper Seam only in the north and northeast of the Ohai district and the northeast of the Nightcaps district. Elsewhere the Morley No.3 seam was located in close proximity to the Morley No.2 seam. In conclusion Bowen (1964) noted that insufficient information was available to define precisely the boundaries between the zones in relation to the stratigraphic sequence through the Morley Coal Measures.

3.3 PROBLEMS RELATING TO THE APPLICATION OF COUPER'S SCHEME TO THE PRESENT STUDY

Table 4 displays the key species and other data employed in the calculation of Couper's zonal indices. Following Couper (1964), the zonal indices were plotted on a log graph for visual interpretation (Fig 8). When the zonal indices for each sample were plotted on stratigraphic drillhole columns (Figure 9) Couper's zones were not recognisable. While some holes appeared to show some semblance of a stratigraphically ordered zonation, all contained incompatible sample horizons. Figure 9 provides a useful reference to the following discussion.

Within the sequence in drillhole 375, five samples assigned to the *P. marwickii* zone occurred stratigraphically below three samples from the *P. mawsonii* zone. Only one sample from the *P. cf. ellipticus* zone was defined and was located between two samples belonging to the *P. marwickii* zone. In drillhole 382 five samples belonging to the *P. cf. ellipticus* zone were located at the top of the hole, while a further four samples belonging to the same zone were located at the base of the hole. Located between these two sample groups were eight samples in an unordered sequence belonging to the *P. marwickii* and *P. cf. ellipticus* zones. In drillhole 335 eleven samples belonging to the *P. cf. ellipticus* zone were located in the mid region of the hole. Of three samples belonging to the *P. mawsonii* zone, two were located at the top of the hole and one amidst the *P. cf. ellipticus* zone samples. Two samples belonging to the

DRILLHOLE 382

	573	572	571	570	569	568	567	566	565	564	563	562	561	560	559	558	557
Podocarpidites cf. ellipticus ...	900	183	200	60	33	44	40	37	24	69	5	25	65	50	190	40	166
Podocarpidites marwickii	200	17	117	25	0	11	68	12	19	69	18	21	20	35	60	20	100
Ratio	4.5	11	1.7	2.4		4	.5	3	1.2	1	.3	1.2	3.2	1.4	3.1	2	1.6
P. cf. ellipticus + P. marwickii	1100	200	317	85	33	55	108	49	43	138	23	46	85	85	250	60	266

DRILLHOLE 335

	534	533	532	531	530	529	528	527	526	525	524	523	522	521	520	519
Podocarpidites cf. ellipticus ...	333	100	28	100	133	80	158	26	120	39	163	84	466	95	27	36
Podocarpidites marwickii	333	83	86	66	78	30	116	10	40	21	63	31	366	16	14	12
Ratio	1	1.2	.3	1.5	1.7	2.6	1.3	2.6	3	1.8	2.5	2.7	1.2	6	1.9	3
P. cf. ellipticus + P. marwickii	666	183	114	166	211	110	274	36	160	60	226	115	832	111	41	48

DRILLHOLE 364

	600	599	598	597	596	595	594	593	592	591	590	L12727/1	L12726/3	L12725/2
Podocarpidites cf. ellipticus ...	175	22	61	37	137	17	3	43	11	43	2.6	47	0	50
Podocarpidites marwickii	58	15	15	31	6	0	10	9	7	86	4.3	63	0	32
Ratio	3	4	4	1.2			.3	5	1.5	.5	.6	.7	0	1.5
P. cf. ellipticus + P. marwickii	233	66	66	68	143	17	13	52	18	129	6.9	110	0	82

DRILLHOLE 336

	555	554	553	552	551	550	549	548	547	546	545	544	543	542	541
Podocarpidites cf. ellipticus ...	30	38	231	86	10	66	0	140	133	120	9	17	18	25	100
Podocarpidites marwickii	10	24	100	26	13	0	0	80	133	80	0	0	0	37	0
Ratio	3	1.6	2.3	3.3	.7		0	1.75	1	1.5				.6	
P. cf. ellipticus + P. marwickii	40	62	331	112	23	66	0	220	266	200	9	17	18	62	100

DRILLHOLE 343

	609	608	607	606	605	604	603	602	601
Podocarpidites cf. ellipticus ...	26	76	0	3	13	58	8.3	16	24
Podocarpidites marwickii	48	125	0	17	7	3	8.3	8	21
Ratio	.5	.6	0	.17	1.8	19	1	2	1.1
P. cf. ellipticus + P. marwickii	74	201	0	20	20	61	17	24	45

DRILLHOLE 375

	628	627	626	625	624	623	622	621	620
Podocarpidites cf. ellipticus ...	35	7	57	133	19	7	21	18	18
Podocarpidites marwickii	70	9	100	100	25	20	16	9	18
Ratio	.5	.7	.57	1.3	.7	.35	1.3	2	1
P. cf. ellipticus + P. marwickii	105	16	157	233	44	27	37	27	36

D.H 384

	649	648
Podocarpidites cf. ellipticus ...	14	60
Podocarpidites marwickii	14	39
Ratio	1	1.5
P. cf. ellipticus + P. marwickii	28	99

DRILLHOLE 347

	580	579	578	577	576	575	574
Podocarpidites cf. ellipticus ...	0	24	45	16	17	67	12
Podocarpidites marwickii	0	3	5	6	3	67	6
Ratio	0	8	9	2.6	73	1	2
P. cf. ellipticus + P. marwickii	0	27	50	22	20	134	18

DRILLHOLE 387

	637	636	635	634	633	632	631
Podocarpidites cf. ellipticus ...	44	58	158	0	0	31	23
Podocarpidites marwickii	25	61	58	172	0	54	54
Ratio	1.7	.9	2.7	0	0	.6	.4
P. cf. ellipticus + P. marwickii	69	119	216	172	0	85	77

Table 4 : Drillholes with data required for implementation of Couper's (1964) scheme.

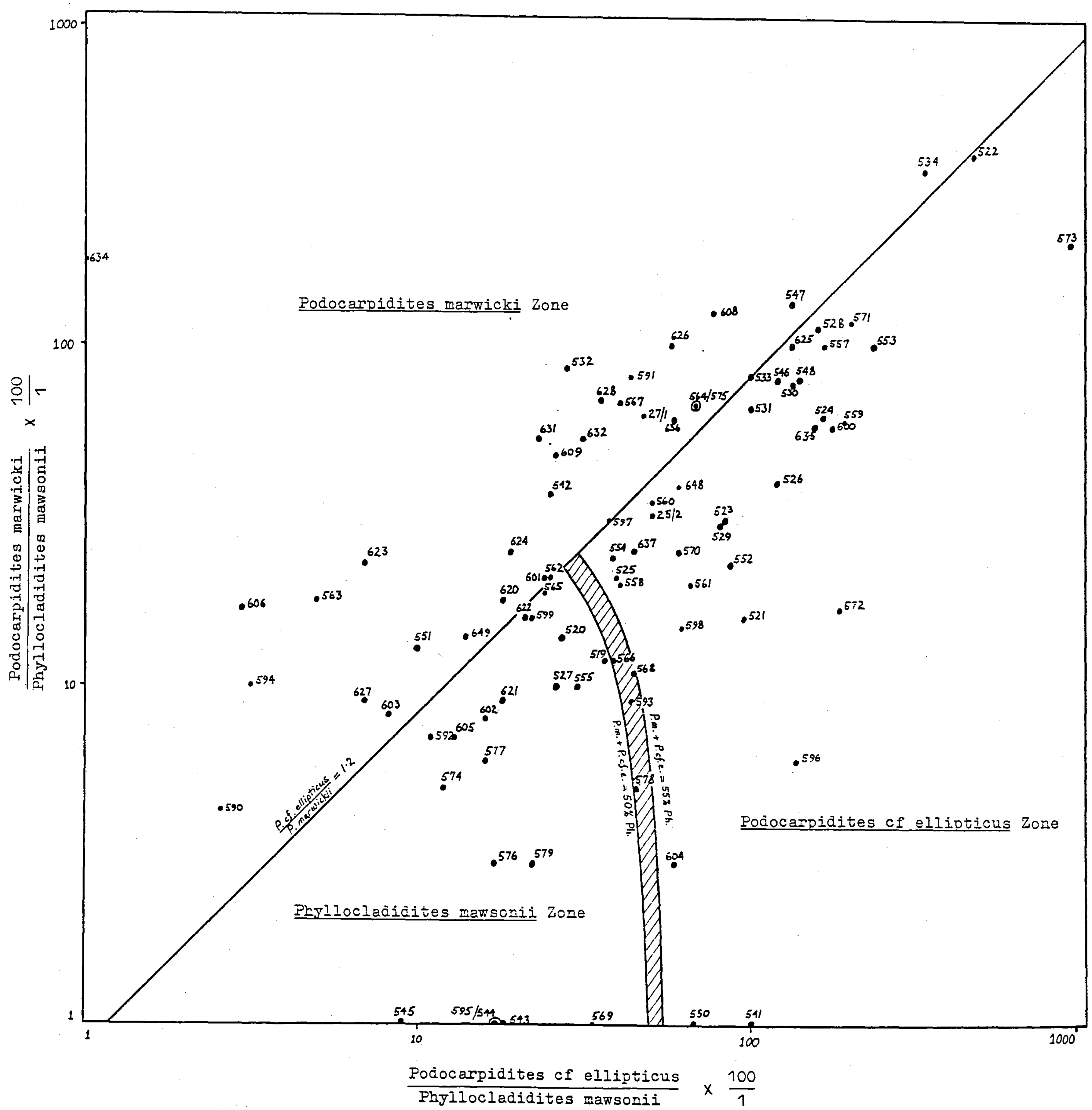


Figure 8 : Logarithmic graph showing sample positions according to Couper's (1964) zonal criteria.

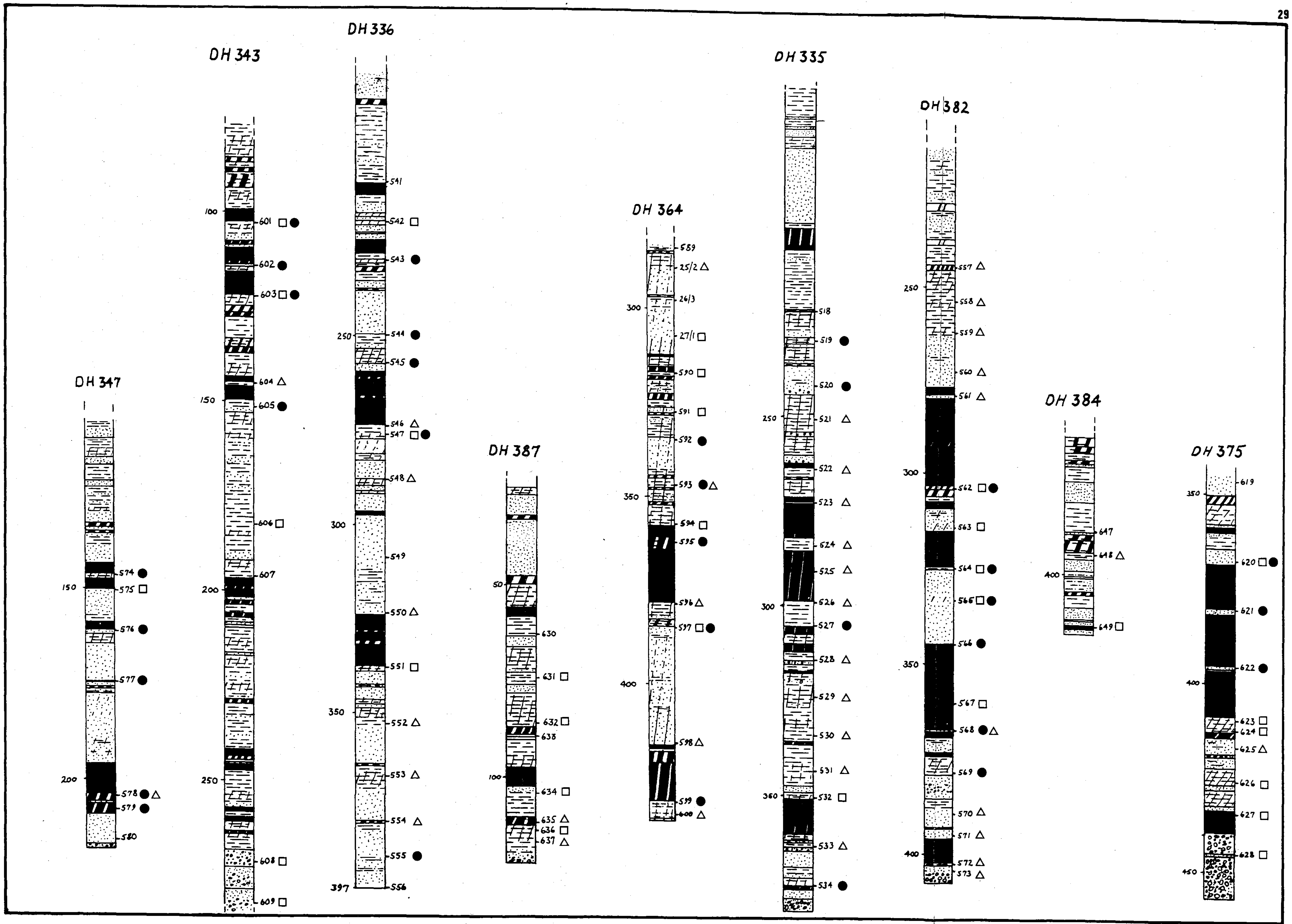


Figure 9 : Drillhole logs showing Couper's zonal indices calculated from data presented in this thesis.

Podocarpidites marwickii zone (upper part of coal measures) . . . .□
Phyllocladidites mawsonii zone (middle part of coal measures) . . .●
Podocarpidites cf. ellipticus zone (lower part of coal measures) . .△

P. marwickii/P. mawsonii Transition zone . . . .□●
P. mawsonii/P. cf. ellipticus Transition zone .●△

P. marwickii zone were located at the base of the hole. The sequence in drillhole 336 had a vague stratigraphically ordered grouping of samples from the *P. mawsonii* and *P. cf. ellipticus* zones, however samples from incompatible zones were interspersed among these samples. In drillhole 343 five samples belonging to the *P. mawsonii* zone were located throughout the length of the hole. Two of these samples occurring near the top of the hole were only marginally within the zonal criteria of the *P. mawsonii* zone. The hole contained one sample assigned to the *P. cf. ellipticus* zone which was located in the upper region of the hole above a *P. mawsonii* zone sample. The majority of samples from drillhole 347 were assigned to the *P. mawsonii* zone; two samples belonging to the remaining two zones were located within this group. Drillholes 387 and 364 were the only holes containing a semblance of stratigraphically ordered zones. Samples from drillhole 387 belonged to the *P. marwickii* and *P. cf. ellipticus* zones though two samples at the zone boundary were reversed and stratigraphically incompatible. Drillhole 364 contained samples belonging to all three zones, however, from the total of 13 samples four were in stratigraphically incompatible positions and two were only marginally within zonal criteria.

Specific aspects of Couper's methodology that caused serious difficulties in the application of his scheme to the present study of the Morley Coal Measures are discussed below.

3.3.1 POLLEN COUNTING

Examination of Couper's relative percentage data showed that the pollen counting technique employed by Couper was not based on a fixed pollen sum (as described in section 2.5). The total number of palynomorphs counted in his assemblage slides ranged from 91 to 426. Nowhere in his publication did Couper elaborate on this pollen counting procedure.

In terms of the statistical validity of recorded assemblages pollen counting is a procedure of considerable importance. Clearly, to achieve accurate palynological analyses, it is essential that each recorded assemblage is as representative of the sample population as possible. Despite the fundamental nature of this operation there seems, as yet, little agreement amongst palynologists concerning the numbers of spores and pollen grains that should be counted in order to attain this objective (see section 2.3). It is generally agreed however, that counts below 150 grains are not representative of the population and should be avoided.

Of the 79 samples used by Couper in his zonal scheme, 21 (26%) had grain counts below 150 (calculated from data tables of Couper 1964 in Bowen 1964). These samples have doubtful statistical value and are likely to contain inaccurate proportions of species and omissions in taxa present in the assemblages. They are considered to be serious sources of error and probably contribute to the general difficulty in application of the scheme to this study.

3.3.2 RELATIVE ABUNDANCE CHARACTERISTICS OF THE KEY SPECIES, *P. MARWICKII, P. cf. ELLIPTICUS AND P. MAWSONII*

Significant discrepancies between relative abundance data of *Phyllocladidites mawsonii*, *Podocarpidites marwickii*, and *Podocarpidites cf. ellipticus* were evident between Couper's study and this project. Several statistical parameters (listed in Table 5) were calculated to facilitate comparison of data. The major discrepancies that became evident were:

(1) the comparatively low abundance values for *P. mawsonii* determined in this study, and

(2) the relative abundances of *P. marwickii* and *P. cf. ellipticus* with respect to *P. mawsonii*.

3.3.2.1 P. mawsonii abundances

Couper maintained that *P. mawsonii* had an unusually high abundance throughout the Morley sequence. Without doubt this is true, however upon comparison of data in Table 5 it was apparent that this abundance was not as high in this study as it was in Couper's. In Couper's data the range of the mean relative abundance ±1 standard deviation for *P. mawsonii* was

COUPER'S (1964) DATA

	n	$\bar{x}$	σ_n	σ_{n-1}	Σx	Σx^2	66.3% of samples have relative abundances of:
Podocarpidites cf. ellipticus..	79	10.59	5.46	5.5	837	11223	5 - 16%
Podocarpidites marwickii.......	77	7.13	4.92	4.95	549	5781	2 - 12%
Phyllocladidites mawsonii......	78	40.11	14.8	14.9	3140	143524	25 - 55%

DATA FROM THIS THESIS

	n	$\bar{x}$	σ_n	σ_{n-1}	Σx	Σx^2	66.3% of samples have relative abundances of:
Podocarpidites cf. ellipticus..	87	4.1	2.5	2.54	361	2051	2 - 7%
Podocarpidites marwickii.......	84	3	2.3	2.3	253	1206	0.7 - 5.3%
Phyllocladidites mawsonii......	93	11.12	10.11	10.17	1044	21244	1 - 21%

Table 5 : Statistical parameters calculated for the three key species *Podocarpidites cf. ellipticus*, *Phyllocladidites mawsonii*, and *Podocarpidites marwickii*, for data in this thesis and for Couper (1964).

25-55% (66.3% of samples fall within this range), while in data from this study the range of the mean relative abundance ±1 standard deviation was 1-21% (66.3% of samples fall within this range). Also, 88% of samples from this study had relative percentages (of *P. mawsonii*) of less than 25% (25% is 1 standard deviation below the mean relative abundance of *P. mawsonii* in Couper's study).

These discrepancies were reflected in the middle and lower zones due to the direct comparison of the combined percentages of *P. cf. ellipticus* and *P. marwickii* to *P. mawsonii*. The probability of assigning samples to the lower (*P. cf. ellipticus*) zone increased while the probability of assigning samples to the middle (*P. mawsonii*) zone decreased.

3.3.2.2 Relative abundances of P. marwickii and P. cf. ellipticus with respect to P. mawsonii

Examination of Table 5 shows that for Couper's data the range of the mean relative abundance ±1 standard deviation for *P. marwickii* was 2-12% (66.3% of samples fall within this range), and for *P. cf. ellipticus* 5-16% (66.3% of samples fall within this range) . The equivalent figures for data of this study (Table 5) were 0.7-5.3% for *P. marwickii* and 2-7% for *P. cf. ellipticus*. In terms of Couper's zonal definitions there is little significant difference between these two groups, however, in order to investigate fully the differences between these two data groups the trend in ranges were taken to the extreme. In this case the range for *P. marwickii* had its lowest value in this study and for *P. cf. ellipticus* the range had its highest value also in this study. In this extreme situation a greater number of samples from this study would have larger ratio values of *P. cf. ellipticus* to *P. marwickii* and would increase the number of samples assigned to the middle and lower zones. Careful inspection of data also showed that 27% of samples from this study had relative abundances of *P. marwickii* and *P. cf. ellipticus* that equalled or exceeded that of *P. mawsonii*. No samples in Couper's study yielded abundances of these two species that were greater than *P. mawsonii*. The effect of this feature was to increase the probability of samples being assigned to the middle and lower zones.

It is clear that the relative abundances of *P. mawsonii* were generally lower in this study than in Couper's. It is also evident that the relative abundance of *P. marwickii* and *P. cf. ellipticus* did not differ significantly from those in Couper's study. In view of these results a greater proportion of samples in this study were therefore assigned to the lower (*P. cf. ellipticus*) zone and a smaller proportion assigned to the middle (*P. mawsonii*) and upper (*P. marwickii*) zones than in Couper's study. The significance of this revised compilation suggests that the relative abundance characteristics of *P. mawsonii* established by Couper were not accurate representations of the species distribution over the coalfield. This was considered to be a major factor contributing to the difficulties experienced in applying Couper's scheme to the present study.

3.3.3 MORPHOLOGICAL DISCRIMINATION OF P. MARWICKII AND P. cf. ELLIPTICUS

During the present study considerable difficulty was encountered in separating *P. marwickii* and *P. cf. ellipticus* on morphological grounds since the formal descriptions of these two species contained few clearly distinguishing features. In particular discrimination centered around the following features: (1) grain dimensions, (2) sacci reticulum development, (3) marginal ridge development and proximal cap exine measurement, and (4) furrow dimensions. To facilitate discussion the formal descriptions are given below (see also Figure 10).

P. ellipticus Cookson from Cookson (1947): Body of grain in polar view broadly elliptical or slightly angular, 29 - 42µm long and 26 - 40µm wide, when expanded. The overall measurement from 45 - 61µm. Exine of cap finely granular and marginal crest developed. Furrow about 18µm wide, its rim not thickened. Air bladders two, rather delicate, sometimes fused, completely bordering the sides of the furrow and extending beyond the poles of the grain, meshes of the mesexinous reticulum small and obscurely defined.

P. marwickii Couper from Couper(1953): Free, anisopolar, bilateral, dissacate. Body of grain elliptical to circular in polar view. Proximal

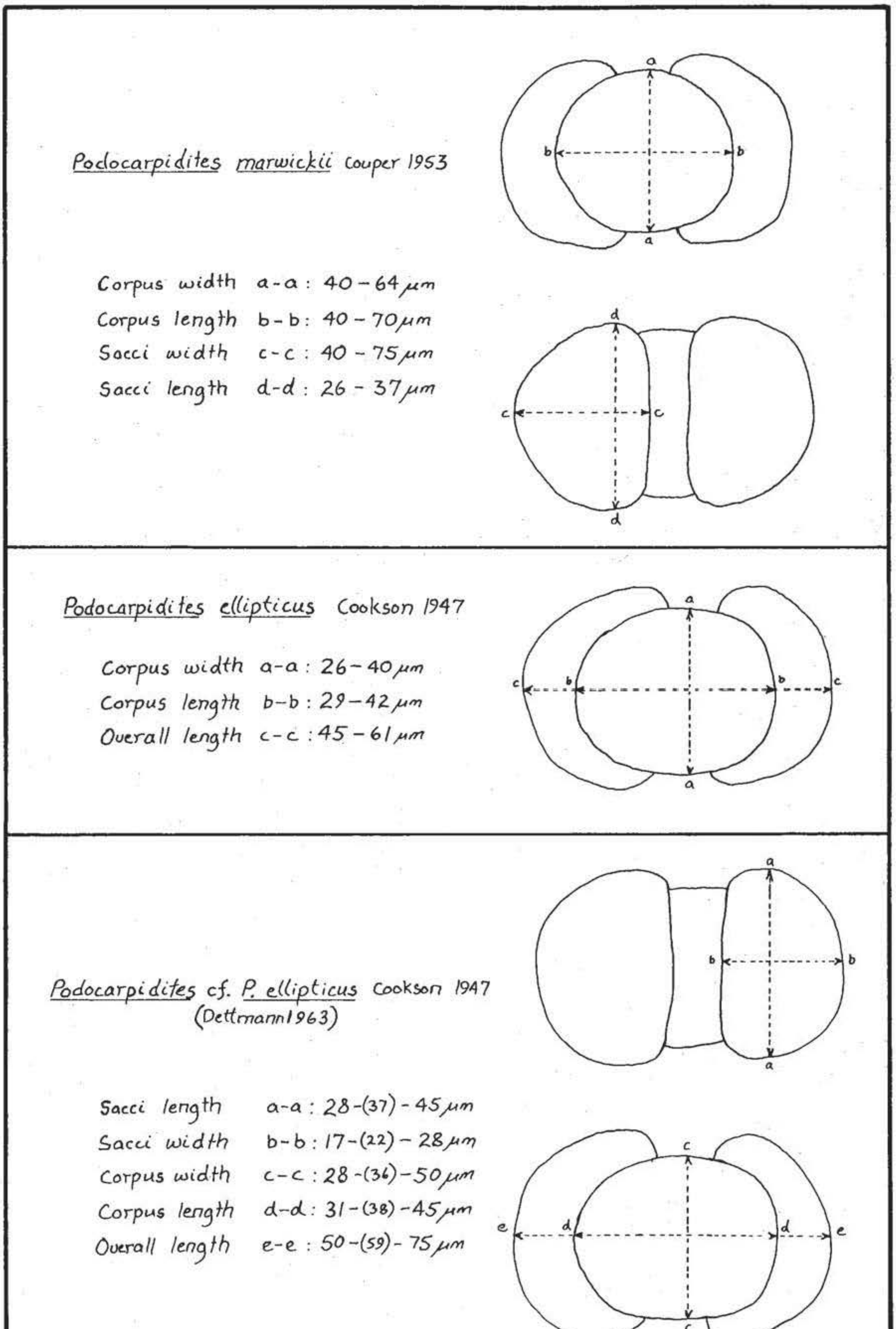


Figure 10 : Dimensions of *Podocarpidites marwickii* Couper 1953, *Podocarpidites ellipticus* Cookson 1947, and *Podocarpidites cf. P. ellipticus* Cookson 1947 (Dettman 1963).

cap finely granular to pitted, occasionally granular, no definite marginal ridge. Sulcus (furrow) psilate. Bladders rather delicate, often crumpled, large with a wide, rather indistinct, incomplete reticulation. Exine of proximal cap 1.5 - 2.0µm thick. Length of grain 40-(55)-70µm; width of grain 40-(44)-64µm; length of bladders 26-(31)-37µm; width of bladders 40-(44)-75µm.

3.3.3.1 <u>Grain dimensions</u>

Podocarp grains morphologically similar to the two species in question with corpus lengths (breadth) in the range 30-45µm were encountered frequently in this study. This range was problematical as it coincided with the upper limits of *P. cf. ellipticus* and the lower limits of *P. marwickii*. Sacci dimensions for the two species were also of little value in providing reliable criteria for identification. Cookson's (1947) description of *P. cf. ellipticus* states that the two sacci completely border the sides of the furrow and extend beyond the poles of the grain. No dimensions were given for the sacci but it seems reasonable to assume they have a minimum width equal to that of the corpus width (the maximum corpus width is 40µm). The maximum sacci width however is unknown and was generally determined through experience and by comparison with other *P. cf. ellipticus* grains. Couper's (1953) description of *P. marwickii* on the other hand gave clear dimensions that allowed the sacci width to be equal to or greater than the corpus width, thus allowing the sacci to extend beyond the poles of the grain as do the sacci of *P. cf. ellipticus*. The formal descriptions give the maximum width of *P. cf. ellipticus* sacci as 40um and the minimum width of *P. marwickii* sacci as 40um. This allowed the sacci of both species to extend beyond the poles of the grain. It is therefore reasonable to expect - and indeed this is the case in this study - that grains of either species will be seen with dimensions that exceed or fall below those given in formal descriptions.

The problem of grain dimensions was highlighted in a discussion by Balme (1957) in which he introduced the name *Pityosporites cf. ellipticus* for pollen grains that agreed closely with *Podocarpidites cf. ellipticus* (Cookson) Couper 1953. This taxonomic approach was adopted for a number of reasons. Balme briefly appraised the misunderstanding existing as to the applicability of the generic name *Pityosporites* and maintained that unless distinctive diagnostic features were evident the use of other names were unwarranted. The generic name *Disaccites* proposed by Cookson (1947 p131) was, according to Balme, by definition, a synonym for *Pityosporites* and was not used by him. In particular Balme noted that, in well preserved assemblages, pollen grains that closely agreed with Cookson were frequently seen but, in poorly preserved assemblages where the finely granular ornament of the proximal cap and the marginal ridge were not easily discernable, the name *Pityosporites cf. ellipticus* was applied. Balme also specified a wider size range, this being due to specimens (from Western Australia) having a total span (maximum length of grain including sacci) of up to 85µm. Cookson's total span was 45 - 61µm.

Further confusion surrounding the dimensions of *P. cf. ellipticus* arises from a detailed study of spores and pollen grains from South-eastern Australian Upper Mesozoic strata by Dettmann (1963). In this study Dettmann described and formally named a grain *Podocarpidites cf. P. ellipticus* Cookson 1947 using *P. ellipticus* Cookson 1947 as the type species. This grain was reported to be similar to Cookson's Kerguelen species, *Podocarpidites ellipticus*, and was common in the Upper Mesozoic of S.E Australia. The following dimensions were given by Dettmann (1963) (see Fig 10): Breadth; overall 50-(59)-75 µm, corpus 31-(38)-45 µm, sacci 17-(22)-28 µm. Length; corpus 28-(36)-50 µm, saccus 28-(37)-45 µm. Depth of corpus 25-(30)-38 µm. It is apparent that these dimensions overlap substantially with those given for *P. marwickii* by Couper (1953), thus confusing the issue of distinction between these two species even further. The overlaps are; corpus length 10 µm overlap, corpus width 5 µm overlap, saccus length 5 µm overlap and saccus width 2 µm overlap. Of particular note also, was that Dettman's dimensions indicated grains had been observed with corpus widths exceeding saccus widths by up to 5 µm, that is, saaci do not always extend beyond the poles of the grain as stipulated by Cookson (1947).

3.3.3.2 Sacci reticulum development

Characteristics of sacci reticulation proved inconclusive in distinguishing *P. marwickii* and *P. cf. ellipticus*. The formal definitions were ambiguous - *P. marwickii*: "... with a wide, rather indistinct, incomplete reticulation ..." ; *P. cf. ellipticus*: "... meshes of the mesexinous reticulum small and obscurely defined ..." - and were of little use in classifying the observed characteristics. Sacci exine appears to suffer readily from corrosion and physical damage; in very few cases was a clearly defined reticulum observed. Even in well preserved assemblages distinction between the two types of sacci was difficult as reticula were generally discontinuous. Dettmann (1963), in her description of *Podocarpidites cf. P. ellipticus* (Cookson 1947), made no mention of sacci characteristics, however sacci mesh can be clearly observed in the excellent plates accompanying the publication where they are definitely not small and obscurely defined as stated by Cookson (1947).

3.3.3.3 Marginal ridge development and proximal cap exine measurement

The formal descriptions of the marginal ridge were vague and of little value in identification problems. *P. marwickii* has "... no definite ridge." ; *P. cf. ellipticus* has "... marginal crest developed." The development of the marginal ridge observed in grains of this study ranged from no ridge at all to well developed ridges. There was no particular tendency to one or other extreme in grains assigned to either species. Often the marginal ridge appeared corroded and reduced; in these cases it could only be termed as slightly developed. The marginal ridge structure is a "protrusion" (Figure 11) and is therefore likely to suffer considerably in oxidising conditions due to its relatively large surface area. It is thus difficult in this case to make presumptions about its original development. Similarly, the proximal cap in grains that had suffered some degree of corrosion was usually reduced so that true exine measurement was impossible. In these cases sculpture of the cap could only be described as having a marginally granular texture.

3.3.3.4 Furrow dimensions

Although Cookson (1947) stated the furrow for *P. cf. ellipticus* to be "about 18μm"; Couper (1953) did not give a dimension for the furrow of *P. marwickii*. However, measurements of a topotype single grain mount prepared by Palynology Section, N.Z.G.S from Couper's original sediment samples gave a width of 10μm. Measurements made on grains identified as *P. marwickii* in assemblages of this study give values of between 10 and 20μm. It was concluded that the width of the furrow is of little

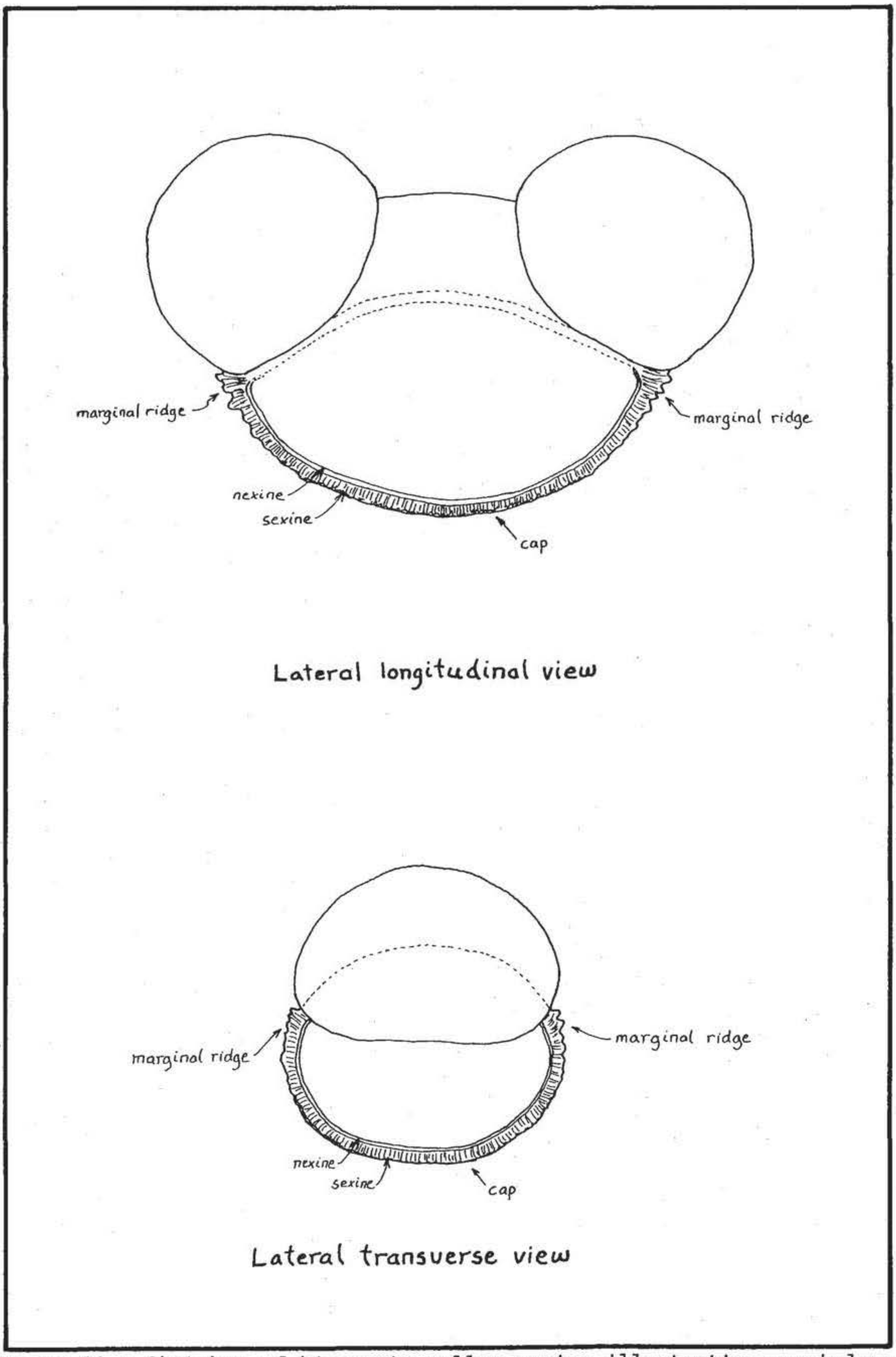


Figure 11 : Sketches of bissacate pollen grains illustrating morphology of the marginal ridge. The marginal ridge is defined by Wodehouse (1953 p543) as "The slightly protruding rim of the cap or disk...", this configuration makes the ridge particularly suscepible to corrosion.

importance in distinguishing between the two species.

3.3.4 COUPER'S NARROW DATA BASE

Couper's biostratigraphical scheme was based on data obtained from drillholes d187 and d171 and the two opencast pits No.7 and No.9. Although Couper (1964) maintained the scheme was generally confirmed by samples from other drillholes and from well correlated seams, it is herein considered - on statistical grounds - that the data base for the scheme was inadequate.

The drill logs for holes d171 and d187 are reproduced in Table 6 and reveal that d171 encountered 8.22 metres of Morley Formation sediments while d187 encountered 117 metres of the formation. Although d171 penetrated all formations in the Ohai Group its use for Morley Formation analysis is of doubtful value. Of the three floral zones distinguished in the Morley Coal Measure Formation the stratigraphically lowest *P. cf. ellipticus* zone was based on samples only from d171 and the No.9 opencast pit which worked the Morley No.3 seam. The fact that 27 samples were used in the determination of this zone was insignificant next to the fact that the stratigraphic column sampled was so limited. This limited range is highlighted next to the fact that the maximum thickness thus far recognised for the Morley Formation is 330 metres.

It is thus suggested that, due to the very short succession of Morley Formation sediments encountered in d171, the sample sequence used was not representative of the formation and may have introduced anomalies into the scheme. In order to obtain a representative section of the Morley Formation, selected holes should contain significant thicknesses of the formation. This appeared not to have been the case in Couper's study.

The two upper floral zones of Couper's scheme were determined from d187 and the opencast pit No.9 which worked the Morley No.2 seam. This hole contained 117m of Morley sediments and was considered to be significantly more representative of the formation than the sequence in d171.

S168/d187

	R20′	Cl.	12	0
		Grl.	20	0
Beaumont Coal Measures	nB18′+	Ms.	38	6
Morley Coal Measures	oM382′+	Ss.	43	0
		Ms.	76	0
	S	COAL	86	6
		Ms.	91	6
		COAL	92	6
		Ms.	95	0
		Ss.	97	6
		Ms.	101	6
		Ms. and COAL bs.	102	6
		COAL	103	6
		Ms. and COAL bs.	106	6
		Ms.	114	0
	M1	COAL	145	0
		Ms. and COAL	197	0
		COAL	198	0
		Ms.	210	0
		Ss.	211	0
		Ms.	240	0
	LM?	COAL	242	6
		Ms.	320	6
		Ss.	365	6
		Dk. ms.	381	0
	M2	COAL	412	9
		Ms.	419	0
		Ss.	420	0

S168/d171, NEW BRIGHTON STATE No. 1

	R6′	Cl.	6	0
Beaumont Coal Measures	nB165′+	COAL and sh. bs.	10	6
		F.c.	11	6
		COAL and sh. bs.	12	6
		F.c.	17	0
		Carb. sh.	19	6
		F.c.	45	0
		Ss.	45	6
		Gr. ms.	55	0
		Soft gr. ss.	56	6
		Soft fn. gt.	71	0
		Hd. fn. gt.	76	0
		Soft fn. gt.	81	0
		Lms.	82	0
		Hd. fn. gt.	112	0
		COAL and sh. bs.	114	0
		Soft ss.	115	0
		F.c.	116	6
		Soft fn. gt.	123	0
		Fn. ss.	123	6
		Br. ms.	149	0
		Soft fn. gt.	152	6
		Carb. sh.	153	6
		COAL	155	6
		Carb. sh.	156	0
		Br. gt.	156	6
		Fn. gt.	171	0
Morley Coal Measures	oM28′+	F.c.	172	0
		Carb. sh., small bs. of COAL	178	0
		Gr. ss.	199	0
Wairio Coal Measures	oN375′	Quartzite gwke and granite cgl.	236	0
		Carb. sh.	237	6
		Fn. gt. and ss. bs.	250	0
		Dk. ss.	271	0
		Cgl.	272	0
		Hd. gr. ss.	273	6
		Cgl.	294	0
		Soft gr. ss.	297	0
		Soft coarse gt.	299	0
		Br. ms.	302	4
		COAL	308	4
		Carb. sh.	310	0
		Gr. ss.	315	0
		Cgl.	388	0
		Dk. ss., carb. strs.	389	0
		Cgl.	416	0
		Sdy. ms.	420	0
		Cgl.	574	0
	oW99′	Ms.	575	6
		Sh.	576	0
		Ms.	585	6
		Sh.	586	6
		Ms.	588	0
		Gr. ss.	598	0
		Ms., carb. strs.	599	0
		Ss.	599	6
		Ms., carb. strs.	614	0
		Gr. ss.	617	0
		Dk. ms., carb. strs.	634	0
		Gr. ss.	643	0
		F.c.	649	0
		COAL	649	6
		F.c.	650	6
		Carb. sh.	652	0
		F.c.	653	0
		Gr. ss.	658	0
		Fn. gt., carb. strs.	661	0
		Gwke cgl.	673	0
	b17′+	Gwke.	690	0

Table 6 : Drill-logs for Couper's drillholes d187 and d171 showing thickness of formations (after Bowen 1964).

Figure 5 shows that d171 and d187 are approximately 5 km apart and that the open cast pits are virtually adjacent to d187. Had there been a greater thickness of Morley Formation sediments in d171 this relatively large distance might have been less significant. The 8.22 metres encountered was considered inadequate for valid analysis, hence this distance between holes was seen as a potential source of error in Couper's scheme. This was attributable to a number of factors, these include:

(1) The area between the holes d171 and d187 contain structural features (faults and folds) that create uncertainties in lateral continuity of the formation, and result in differential thickness preservation.

(2) The period of uplift and erosion following the deposition of the Morley Formation resulted in significant quantities of the formation being differentially removed.

(3) Lateral facies changes and associated erosional periods occurred during the deposition of the Morley Formation resulting in differential thickness preservation.

3.4 CONCLUSIONS

The biostratigraphic zonation of the Ohai coalfield established by Couper (1964) has been demonstrated to contain anomalies. Results from this study indicate that in the Morley Coal Measures the scheme is unusable. These anomalies revolve around:

(1) The pollen counting technique employed by Couper. This technique left a significant number of Couper's samples with statistically invalid floral representation.

(2) The relative abundances of *P. mawsonii*, *P. marwickii* and *P. cf. ellipticus*. These species were used to determine zonal criteria, however the abundances recorded in data of this study revealed serious discrepancies.

(3) The identification problems surrounding *P. marwickii* and *P. cf. ellipticus*. Considerable difficulties were encountered in distinguishing these two species which play major roles in Couper's zonation.

(4) The inadequate data base used in Couper's zonation. The

biostratigraphic palynology used in the scheme did not have a broad enough data base to allow accurate resolution of the structurally complex Morley Coal Measures.

CHAPTER 4

ZONATION OF THE MORLEY COAL MEASURES

4.1 INTRODUCTION

At present, the only palynological zonation applied formally to late Cretaceous terrestrial rocks in New Zealand is that of Raine (1984) for the West Coast Region, South Island.

Many spore and pollen taxa used by Raine in the establishment of his West Coast zonation were found at Ohai and almost certainly Raine's zonation is applicable there. However, the resolution offered by Raine's zonation was too coarse to provide the biostratigraphic precision required at Ohai. For example, all of the Morley Coal Measures appeared to fall within a single zone (PM2) of Raine's scheme.

As a consequence biostratigraphic subdivision of the Morley Coal Measure sequence was investigated by the application of several quantitative techniques. These entailed construction and analysis of:

(1) Standard pollen diagrams based on relative abundances of selected taxa or groups of taxa.

(2) Pollen diagrams zoned by the numerical method of cluster analysis.

(3) Ratios of selected taxa of recurrent but variably high frequency.

Figure 12a-i (in map pocket) shows the distribution of species in order of first appearence for individual holes.

4.2 POLLEN MORPHOLOGY AND MODE OF DISPERSAL.

The theoretical basis for the application of pollen diagrams is well established (Birks and Birks 1980, Faegri and Iversen 1975). Of particular importance in the interpretation of diagrams is the recognition of both the productivity and mode of dispersal of the individual pollen and spore taxa. In both Recent and Quaternary studies, both characteristics can be readily ascertained. Furthermore, the relationships between spore and pollen morphology and mode of dispersal are easily distinguished, in particular morphological distinctions between wind (anemophilous) and insect (entomophilous) pollinated types. In the pre-Cenozoic samples of the Morley Coal Measures, however, the affinities of individual spore and pollen to plant taxa were, in most instances unknown. In such cases, mode of dispersal was inferred solely by reference to pollen morphology of comparable extant taxa of known dispersive mode. On a regional scale, clearly wind pollinated pollen are most likely to be widely and abundantly distributed. Consequently for optimum coal seam correlation at Ohai, attention was focused on pollen inferred to be anemophilous.

Morphological features used to identify anemophilous pollen and to distinguish them from entomophilous and autogamous (self pollinating) pollen were:

(1) The possession of sacci, such as those characteristic of the Podocarpaceae.

(2) Size ranges: anemophilous grains generally fall within the size range of 15-100μm (McGlone, cited in Browne 1986). Outside of this range grains are considered too small or too large for efficient dispersal.

(3) Reduced ornamentation of exine: anemophilous grains such as Fagacaeae and Podocarpaceae tend to lack processes that act as ensnaring anchors that might cause clumping of grains or attachment to foreign bodies such as insects.

4.3 CONSTRUCTION OF POLLEN DIAGRAMS

For each drillcore sample, strewn mounts of pollen and spore residues were systematically scanned and relative abundances of individual taxa thereby established. These were expressed as a percentage of a pollen sum. Several different kinds of pollen sum were constructed in order to ascertain the relative sensitivity of different taxonomic groupings of pollen to biostratigraphic zonation. These were:

(i) **Pollen sum Type 1 (all taxa)**

All taxa with the exception of those with abundances less than 1% were used in this sum. Being the pollen sum comprising the greatest variety of spore/pollen taxa, and thus subject to the greatest degree of variability, it was considered unlikely that any meaningful recurrent taxonomic patterns in samples either within or between drillholes would be detected. Only at lower stratigraphic levels, where *Tricolpites reticulatus* was abundant was the pollen sum of any use. Noticeable also, on a gross scale, was a general inverse relationship between the Sporites group on the one hand, and Podocarpaceae, Fagaceae, Proteaceae and other angiosperms on the other.

(ii) **Pollen Sum Type 2 (Podocarpaceae and Fagaceae)**

This group consisted of all pollen types identified as Podocarpaceae and Fagaceae. Out of all likely anemophilous pollen found in the assemblages the pollen from these two plant families were considered to best reflect trends in regional paleo-vegetation. Like their modern counterparts, such pollen were regarded as indicators of forest paleo-environments with wide dispersal capabilities.

(iii) **Pollen Sum Type 3 (Podocarpaceae)**

This pollen sum differs from type 2 in being confined exclusively to Podocarpaceae. The only species of Fagaceae observed in Morley Coal Measure samples, *Nothofagus kaitangata*, while particularly abundant in lower units of the Ohai Group where it had zonal application (Couper 1964), gradually declined in relative abundance through the Morley Coal Measures. It was omitted from this pollen sum to determine any masking effects it may have had on the frequency pattern of the remaining anemophilous taxa.

By assembling consecutive values of pollen and spore taxa, determined from pollen sums of like type, in stratigraphic sequence, composite pollen diagrams were constructed for each drillhole. Pollen diagrams of all drillholes were then aligned to ascertain whether or not any recurrent patterns, that might prove useful in regional correlation, could be detected. Recognition of such recurrent patterns were used to define pollen zones which were, effectively, bodies of sediment with relatively consistent and homogeneous pollen and spore content. Such entities were distinguishable from adjacent sediment bodies by differences in the kind and frequency of contained fossil spores and pollen.

Variability in relative abundances and distribution patterns of observed taxa led to the recognition of two discrete types of zone. Two zones, recognisable by maximium abundances of a single species, were in essence acme zones. A further zone based on a distinct association of taxa fell within the category of an assemblage zone.

4.4 ZONATION BASED ON POLLEN DIAGRAMS OF RELATIVE ABUNDANCE

The principal criteria used in pollen diagram zonation were the patterns of relative abundance of key taxa and groups of taxa that were recurrent throughout the study area. Routine inspection of pollen diagrams revealed several distinctive signatures in the relative frequencies of a number of pollen taxa and groups of taxa. From these signatures it was possible to distinguish three discrete zones each seperated above and below by intervals of indistinct palynological character. These were, in descending order:

(1) The *Nothofagus kaitangata* acme zone,
(2) The SPPA assemblage zone,
(3) The *Tricolpites reticulatus* acme zone.

Of these zones however, only the middle one (the SPPA zone) could be defined as an assemblage zone of the kind generally used in pollen diagram zonation. The *Nothofagus kaitangata* and *Tricolpites reticulatus* zones were based on the maximum abundance of single species - *Nothofagus kaitangata* and *Tricolpites reticulatus* respectively - and hence represent acme zones. By contrast, the SPPA zone was clearly an assemblage zone, defined by the distinctive association of the maximum frequency peaks of the Sporites and Proteaceae groups and the podocarp *Phyllocladus paleogenicus*, and the <u>minimum</u> frequency of occurrence of the anemophilous group. Although *P. paleogenicus* is an anemophilous pollen grain and is included in the anemophilous group, its individual frequency signature had a distinctive recurring peak of maximum abundance. This signature, which tended to be masked when combined into the anemophilous group frequency pattern, was regareded an important zonal indicator.

In summary, the Morley Coal Measures were subdivided into three zonal units, two interzonal units and two bounding unzoned units (Figure 13, in map pocket). As the contact between the Morley Coal Measures and the overlying Beaumont Coal Measures was everywhere an unconformable one the stratigraphic interval between the uppermost *N. kaitangata* acme zone and the overlying formation was deemed unzonable. It was thus named the Upper Unzoned Interval. Similarly, at the base of the Morley Coal Measures where the boundary with the underlying New Brighton Conglomerate appeared conformable in some parts of the coalfield and unconformable in others (section 1.4.1), a lower unzoned interval was recognised. The two interzones (Interzone 1 and Interzone 2) lacked any distinctive pollen signature, and were defined on their intervening relationships between the three pollen zones.

4.4.1 LOWER UNZONED INTERVAL

Coal seams in this stratigraphic interval were confined to the southern-most drillholes 335, 382 and 375, which were inferred to be:

(1) In a deeper part of the basin than the remaining holes further to the north, and

(2) Situated in the present synclinal areas where a general thickening of sediments and coal seams was evident (section 1.4 and 1.5).

It is inferred that the absence of coal seams of significant thickness in the northern drillholes was the result of non-deposition and/or erosion.

4.4.2 *TRICOLPITES RETICULATUS* ACME ZONE

This zone was defined by the *Tricolpites reticulatus* high frequency peak calculated from Pollen Sum Type 1 data. This peak, located low in the sequence, was identified in five holes. Of the remaining holes, drillholes 375 contained a maxima located midway in the sequence and drillhole 347 contained no significant high frequency peak at all (Figure 14).

The stratigraphic position of the high frequency peak in drillhole 375 was not easily reconcilable with other holes (Figure 14). This peak may represent a further *T. reticulatus* maximum higher up in the sequence. This was indeed possible as other major peaks did occur in other drillholes higher in the sequence, however, none of these peaks exceeded the dominant maxima found lower in the sequence. It was thus inferred that the *T. reticulatus* peak high in drillhole 375 delineated the *T. reticulatus* acme zone in this drillhole, in which case the coal seams below it are assigned to the Lower unzoned interval. This was not unrealistic when the geological history of the basin is considered. The depositional basin in which drillhole 375 is located (Mossbank Basin) was well protected from major sediment input from the north by the Bluebottle and White Range paleo-highs (Bowman et al 1987)(Figure 15). The Ohai basin in which the remaining drillholes were located appeared not to have had such protection. It was inferred that, as a result of this lack of protection, the lower most coal seams in the Ohai basin suffered erosion and/or non-deposition to an extent that was not prevalent in the Mossbank basin. The location of the SPPA assemblage zone above this unit is compatible with this theory although it implies the Interzone 1 unit wedges out at or before this drillhole (Figure 13). In order to resolve this issue an analysis of drillhole 371, located midway between drillholes 375 and 384, would need to be conducted.

The absence of the *T. reticulatus* maxima in drillhole 343 (Figure 14) was, in all likelihood, accounted for by the absence of core between 196.85 metres and 269.25 metres, a thickness of 72.4 metres, all of which was in the Morley Formation. It was in this interval that the *T. reticulatus* maxima would have been expected to occur given that the SPPA assemblage zone was located immediately above this non-cored interval (Figure 13, drillhole 343). The conformation of this zone in drillhole 343 rests with the analysis of open hole cutting samples which,

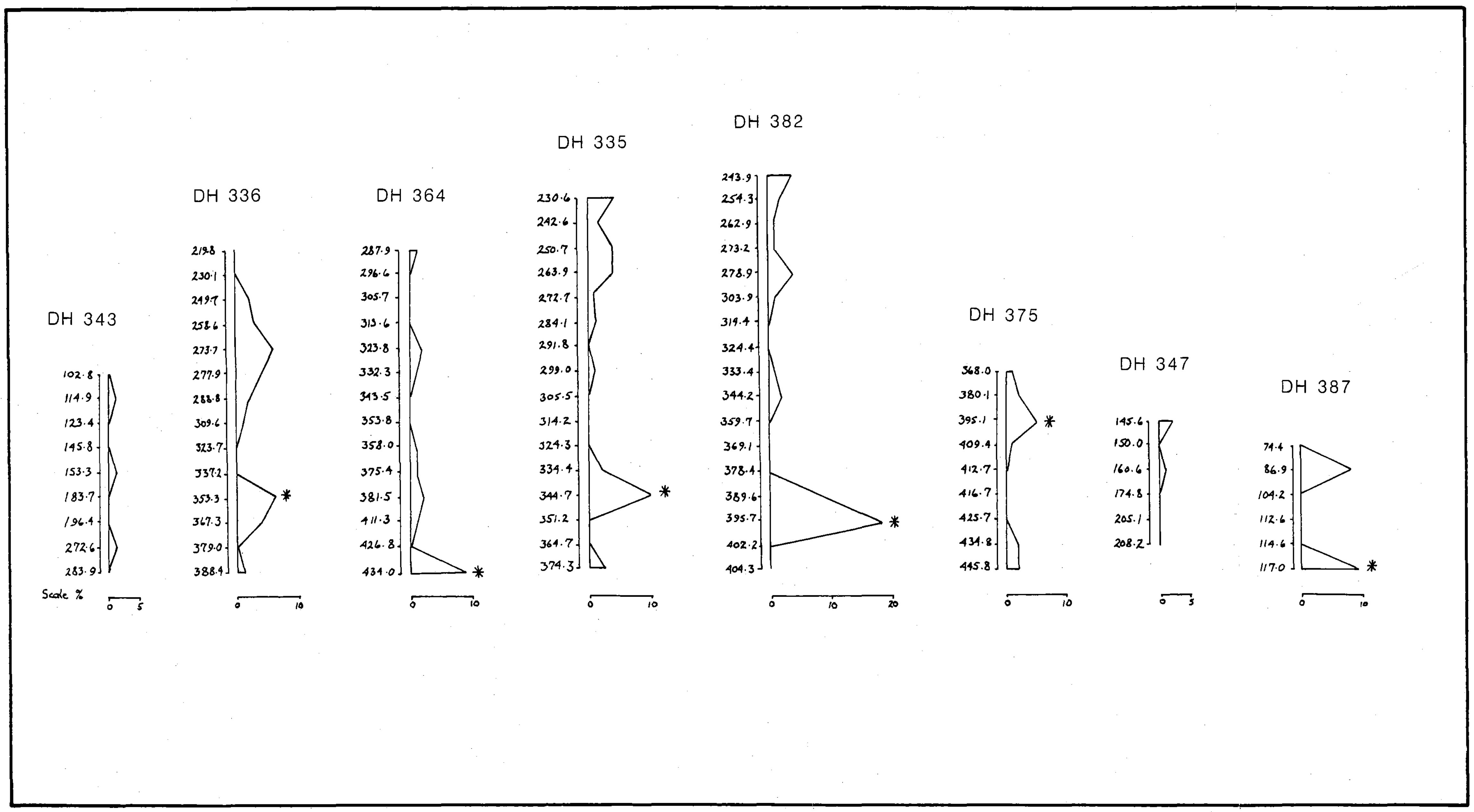


Figure 14 : Pollen diagrams of *Tricolpites reticulatus* used to distinguish the *Tricolpites reticulatus* acme zone - denoted by an *

Figure 15 : Paleobasins and highs affecting the Morley Coal Measure deposition (From Bowman et al 1987)

while being undesirable for palynological use (section 2.1), and were not used in this project, may satisfactorily indicate the presence of the zone.

No abundance peak that could confidently be designated as the *T. reticulatus* acme zone was sufficiently prominent in drillhole 347. (Figure 14). The *T. reticulatus* values in the upper region of the hole represent low raw counts and thus have doubtful value in terms of defining the zone. In addition, and most importantly, the SPPA assemblage zone was located at 205.15 metres which rendered the *T. reticulatus* occurrences in the uppermost part of the drillhole invalid as locations for the zone. It was inferred that the part of the sequence assigned to the *T. reticulatus* zone was absent, this being most probably attributable to non-deposition and/or removal by erosion. In addition, drillhole 347 was located in a complicated fault controlled area (Figure 5, Chapter 2), the effects of which, undoubtably contributed towards the absence of parts of the sedimentary succession.

The maximum abundance peaks of *T. reticulatus* in drillholes 336, 364, 335, 382 and 387 were clearly defined (Figure 14). Although drillhole 336 and 387 had an additional peak of similar magnitude its location in the upper region of the respective holes discounts it as the zone marker. In addition, the position of the SPPA assemblage zone also controled the position of the *T. reticulatus* zone in those drillholes.

4.4.3 SPPA ASSEMBLAGE ZONE

This zone was delineated by:

(1) The high frequency peak of *Phyllocladus paleogenicus*, calculated from Pollen Sum Type 2 data.

(2) The high frequency peaks from the Sporites and Proteaceae groups, calculated from Pollen Sum Type 1 data.

(3) The minimum frequency value for the anemophilous group, calculated from Pollen Sum Type 2 data.

When the pollen diagrams for each hole were placed in alignment with all depth values corresponding, the frequency peaks and troughs in

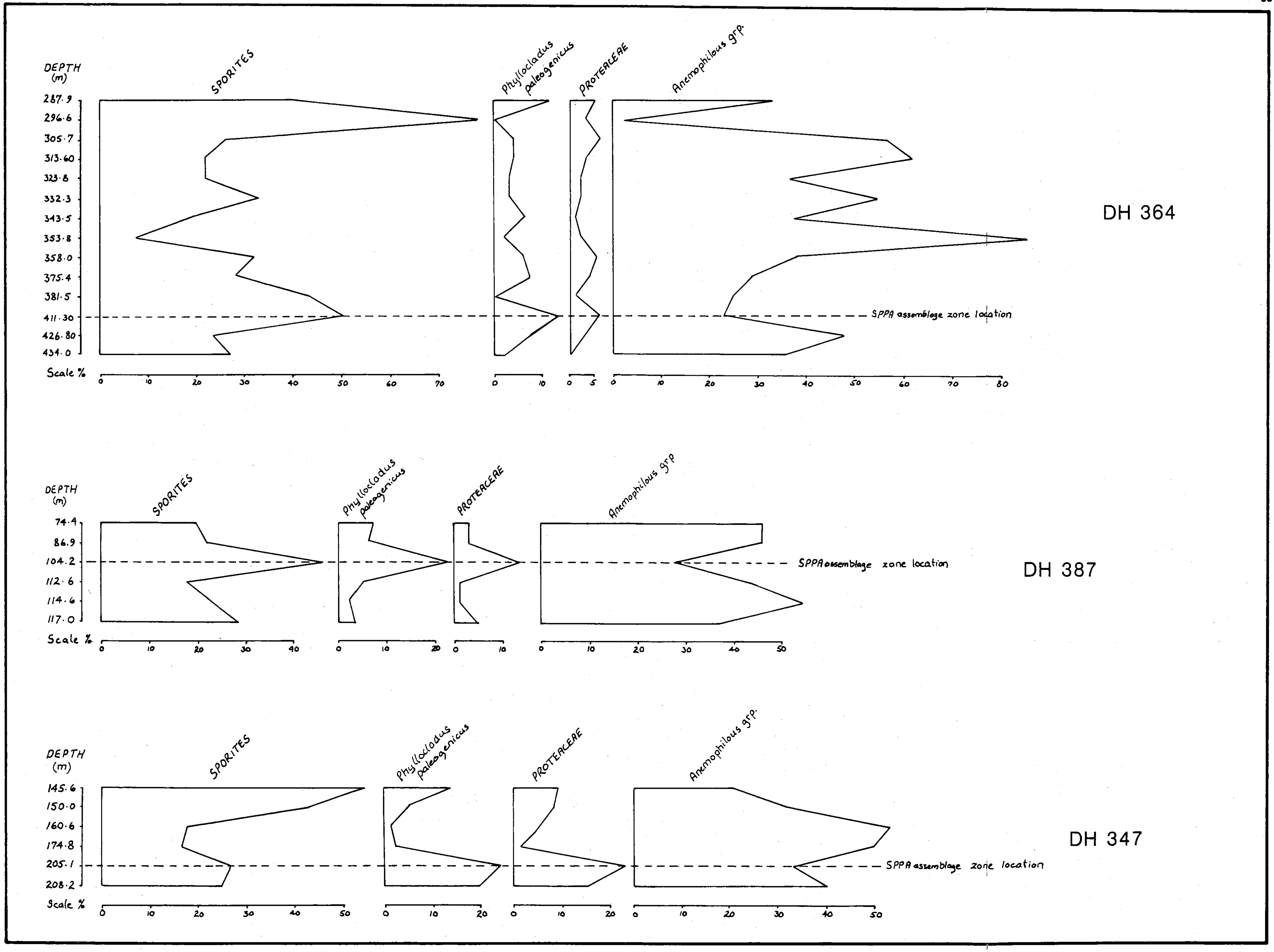


Figure 16 : Pollen diagrams distinguishing the SPPA assemblage zone. The Sporites, Proteaceae and Podocarpidites/Fagaceae diagrams were calculated from pollen sum 1 data and the *Phyllocladus paleogenicus* diagram from pollen sum 2 data.

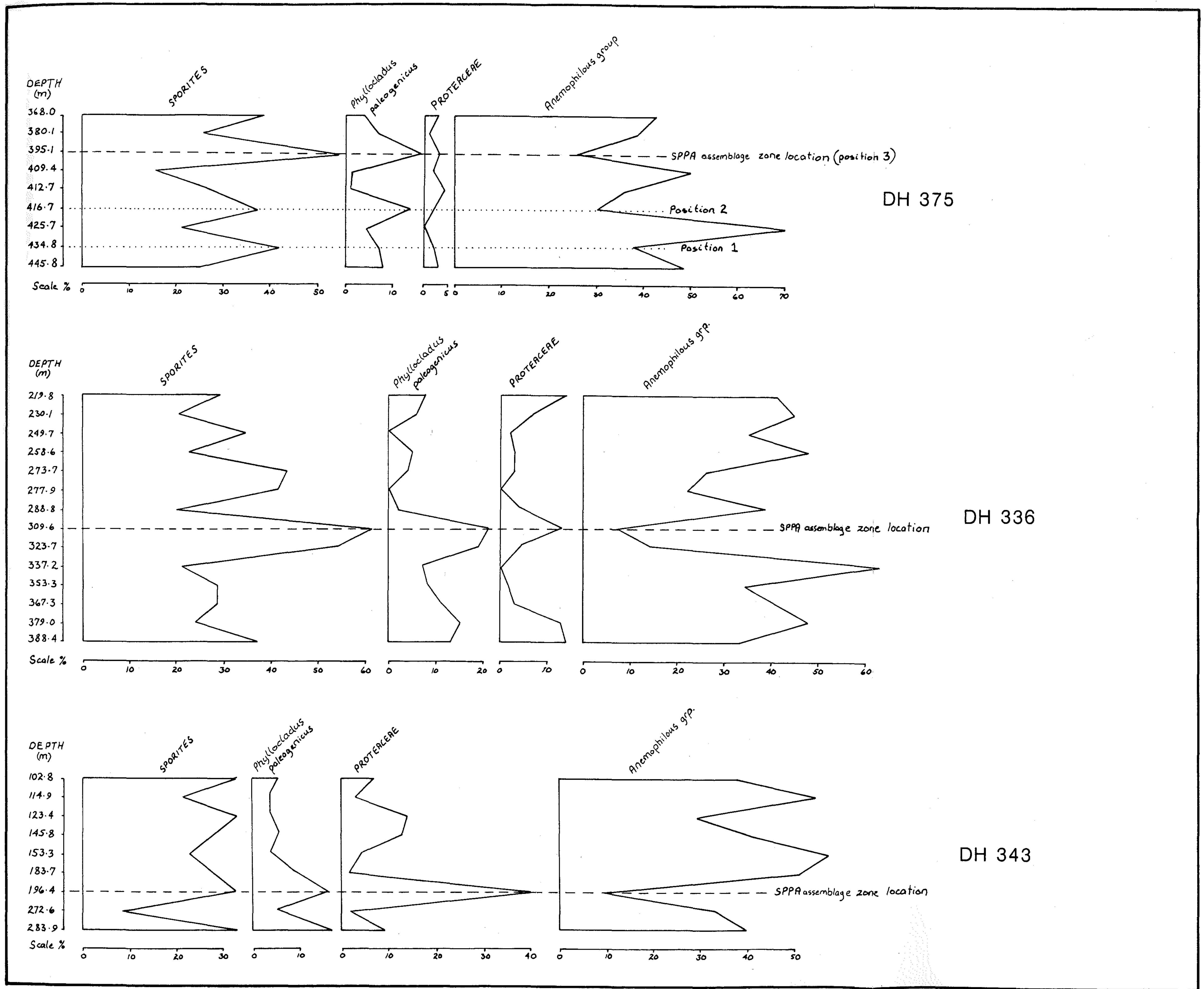
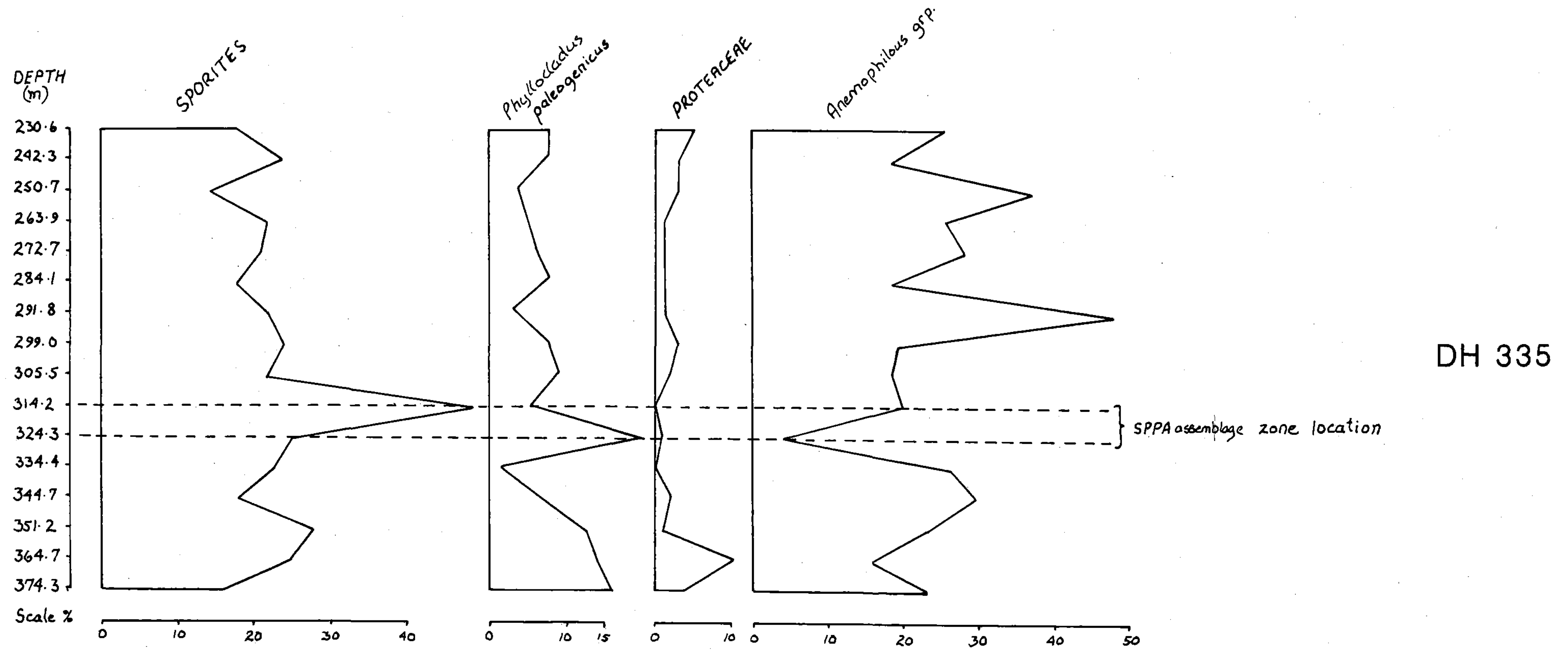


Figure 16 : continued



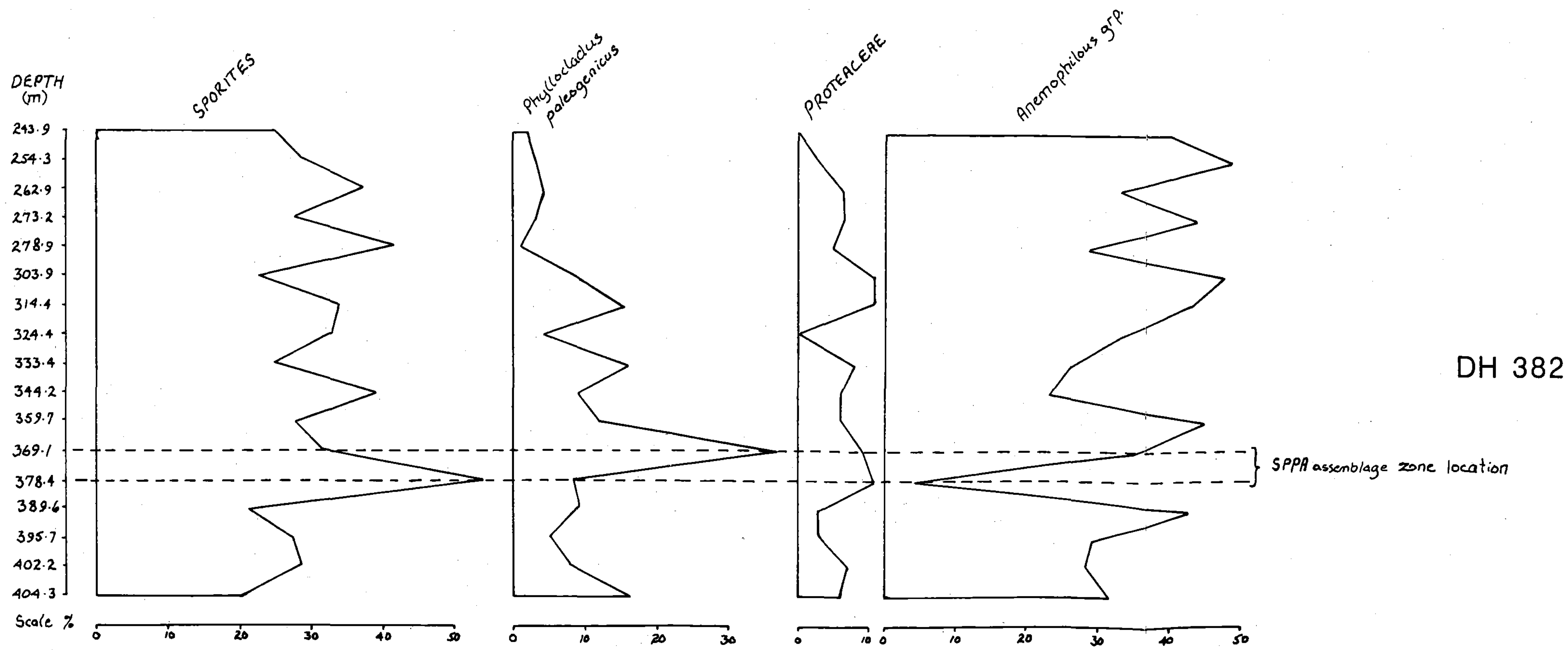


Figure 16 : continued

question had remarkable stratigraphic consistency of (stratigraphic) position (Figure 16).

The Sporites group as a whole yielded a distinct and recurrent high frequency peak in the lower part of all drillhole sequences (Figure 16). In drillholes 343 and 375, more than one peak was evident. However, by utilizing the remaining entities of the assemblage zone it was clear which of the frequency maxima were part of the zone. Drillhole 343 did not have a prominent Sporites group peak, however drillcore was not continuous in this hole and below the sample location to which the Sporites group peak was assigned, a gap of 76.25 metres occurred before coring recommenced. It was inferred that the Sporites group peak was, in all probability located immediately below this sample level.

Drillhole 375 contained a number of anomalies which allowed several interpretations to be made. Without a more detailed palynological analysis involving a closer sampling interval than presently used the resolution of these anomalies could not be achieved. It was evident from the cross-section (Figure 17) that the Morley Formation thinned significantly to the southeast, particularly near drillhole 371 and, to a lesser extent, in the vicinity of drillhole 375. The significance of this thinning in terms of the paleo-environment and paleo-vegetation, was difficult to ascertain from available data. If the thinning was merely a result of a reduced sediment load entering the depositional basin, one would still have been expected, in all likelihood, to have found the main zonal markers. However, if the thinning was a result of erosion, then some, or all, of the pollen zones could have been removed. It is suggested that the former possibility was the more likely because:

(a) It was apparent that the thinning of the formation occurred to the southeast of the Bluebottle paleo-high. This suggests, as indicated in section 4.1, that the paleo-high protected the basin from major sediment input from source areas to the north. The depositional basin to the northwest of this paleo-high did not have the same protection and was thus significantly thicker.

(b) In drillhole 375, coal seam thickness was of the same order as those in drillholes to the northwest of the paleo-high. If significant erosion had occurred the coal seam geometry and thickness would be expected to reflect such event(s). Closer to the Bluebottle paleo-high - ie drillhole 371 - coal seams were thinner and fewer in number. Periods of erosion may well have occurred in conjunction with the natural lapping or thinning of the formation onto or over the paleo-high margin.

The palynological data recovered from drillhole 375 indicated that all three pollen zones were present though not well defined in the sampled sequence. The SPPA assemblage zone had three possible positions (Figure 16, drillhole 375). The lower position (1) was initially suggested because the Sporites group abundance peak and anemophilous group abundance minima that define it, were located low in the drillhole, which was in keeping with the patterns in other holes. However, in addition to the absence of the Proteaceae group and *P. paleogenicus* high frequency peaks, this was deceptive due to the variability in thickness and lateral extent of preserved sedimentary units found in the Morley Formation. Position (2) was defined by Sporites group and *P. paleogenicus* abundance peaks and the anemophilous group minima. The absence of a Proteaceae group high frequency peak cast some doubt on the reliability of this position, particularly as the Sporites group peak did not reflect the maximum abundance of the group and neither did the anemophilous group minima represent the minimum value for its group. Position (3) was favoured for two reasons:

(1) It was defined by abundance peaks and troughs of all the appropriate groups, and

(2) The abundance peaks with the exception of the Proteaceae group were maximum values and the abundance level for the anemophilous trough was the minimum value. The Proteaceae group anomaly was difficult to explain and in all probability could only be resolved by more refined sampling.

The SPPA zone in drillhole 382 probably spanned two adjacent sample localities (Figure 16). It was clearly defined by the Sporites and Proteaceae group maximum abundance peaks, and the anemophilous group minima at 378.40 metres. The *P. paleogenicus* maximum abundance peak was also clearly discernable and lay 9.22 metres above the horizon at 369.18 metres. It is suggested the zone lies across these two sample horizons.

A similar situation existed in drillhole 335 (Figure 16). In this case the *P. paleogenicus* maximum abundance peak and anemophilous group minima with a minor Proteaceae high frequency peak providing secondary confirmation, defined the lower limit of the SPPA zone at 324.34 metres. The maximum abundance peak of the Sporites group fell one sample (10.05m) above this lower limit and indicated the upper limit of the zone. While the limitations of using spore taxa as indicators of changes in paleo-vegetation have been discussed earlier Section 3.1), the lateral consistency of the high frequency peak of this group throughout the drillhole sequence suggests its reliability as an indicator.

In drillhole 364 the SPPA zone was defined by the correlation of all four units of the assemblage zone (Figure 16) at 411.30 metres. An anomalous but discountable feature occurred near the top of this hole at 296.53 metres. Here the maximum abundance curve for the Sporites group occurred in conjunction with the minimum abundance value for the anemophilous group. The fact that these two positions represented maximum and minimum values respectively was initially disconcerting, however due to this horizon occurring almost at the top of the formation and with the respective *P. paleogenicus* and Proteaceae patterns showing very low values (zero in the *P. paleogenicus* case) this anomaly was deemed of no major concern.

The SPPA zone was unequivocally defined in drillhole 336 at 309.69 metres by perfectly matched maximum abundance values for *P. paleogenicus*, the Sporites and Proteaceae groups, and the minimum abundance value for the anemophilous group (Figure 16).

The SPPA zone was located at 196.40 metres in drillhole 343 (Figure 16). The Proteaceae group and *P. paleogenicus* maximum abundance peaks and minimum abundance value of the anemophilous group were clearly aligned forming a positive correlation. The Sporites group high frequency peak was not distinct, in fact four high frequency peaks all of which held the same value existed. However, the strong correlation indicated by the other three entities, when projected on to the Sporites group pollen diagram, coincided with a high frequency peak. This peak was considered to indicate the position of the SPPA zone in the Sporites group.

Less than 100 metres of Morley Formation sediments were preserved in drillhole 347 (Figure 34). Due to the geographic location of the drillhole with respect to the other holes, the intense faulting of the immediate area and the incomplete core sequence, difficulties arose in the discrimination of all zones in this hole. Two locations were considered possible for the SPPA zone. The first, at 145.69m, the uppermost sample location in the drillhole, was indicated by the maximum high frequency peak for the Sporites group, high frequencies for the Proteaceae group and *P. paleogenicus*, and low frequency values of the Anemophilous group. However, identification of the *N. kaitangata* acme zone at 150.00m indicated this first position to be unsuitable. The second and most favoured position lay at 205.15m. Here, high frequency peaks of the Proteaceae group and *P. paleogenicus* coincided with the secondary high frequency peak of the Sporites group and minimum for the Anemophilous group.

Drillhole 387 had similar complications to drillhole 347 in that only a short sequence (approximately 58 metres) of the Morley Formation was preserved (Figure 34). The situation was further complicated by the location of the hole toward the margin of the Ohai depositional basin. Given the geological history of the area and the distance of the drillhole from the northern fault bounded margin of the basin (section 2.3 and 2.4) it is inferred that the formation in this area thinned towards and/or lapped onto the basin margins (Figure 17). The geological controls operating at the time of deposition - folding, faulting, periods of erosion, and facies changes, created considerable problems in interpreting the zonal sequences preserved. In view of this, the clearly defined SPPA zone evident in this hole was extremely useful. The maximum abundance peaks of the Sporites, Proteaceae and *P. paleogenicus* units, and the minimum value for the anemophilous unit all occurred at 104.29 metres (Figure 16). The absence of any anomalous patterns in the these floral units confirmed the location of this zone.

4.4.4 *NOTHOFAGUS KAITANGATA* ACME ZONE

This zone is defined by the *Nothofagus kaitangata* high frequency peak which was defined in pollen diagrams derived from both Pollen sum 1 and Pollen sum 2 data. This peak, located high in the sequence was identified clearly in five drillholes. In the remaining drillholes, 343, 364 and 382, discrimination of the zone was less certain (Figure 18).

The complications in drillhole 343 arise from conflicting data from Pollen Sums 1 and 2. While pollen sum 2 data was assumed to reflect regionally derived taxa more accurately than pollen sum 1 data, it was evident upon inspection of pollen diagrams (Figure 18, A and B) that frequency patterns in pollen sum 2 data yielded no obvious maxima. Pollen sum 1 pollen diagrams however, contained a fequency maxima at 114.9 metres. This location was inferred to define the *N. kaitangata* acme zone.

Drillhole 364 had two adjacent abundance peaks that could be correlated with the *N. kaitangata* zone. The peak of maximum abundance fell at 343.55 metres and although occurring relatively low in the sequence, had reasonable correlation with other holes (Figure 18).

The location of the zone in drillhole 382 fell between 243.92 and 254.36 metres. The high frequency peak immediately below this level at 273.29 metres was not considered part of zone because:

(1) the peak was defined by only one sample and had a lower abundance value than the suggested peak (albeit a small difference), and

(2) The frequency values over the first three samples, which increased toward the top of the cored sequence suggest that the true acme of *N. kaitangata* may in fact be present above 243.92 metres. Thus the zone may extend in to the unsampled and uncored part of the drillhole above the first sample at 243.92 metres.

Drillholes 336, 335, 375 and 347 had clear *N. kaitangata* high frequency peaks at 230.11 metres, 250.70 to 263.92 metres, 368.02 to 380.11 metres, and 150.00 metres respectively (Figure 18) and require no further discussion. Drillhole 387 however, had two high frequency peaks.

While the lower peak contained the maximum value the upper peak at 74.41 metres was inferred to be the zone marker in view of the positions of the other zones in this hole (Figure 13).

4.4.5 UPPER UNZONED INTERVAL

This unit was bounded below by the *N. kaitangata* Acme zone and above by the Beaumont/Morley formations contact (Figure 13). As has been discussed in chapter 5, the location of the Beaumont/Morley boundary was a routine procedure and could be accurately determined. In the upper unzoned interval the northern most drillholes 336, 343 and 347 contained two thin - 2 to 5 metre thick - coal seams that were almost certainly correlative with each other (Figure 13) and which thined to the south. The remaining drillholes contained minor coal seams of varying quality with the zone in general consisting of mudstones and sandstones with carbonaceous contents of varying degree.

4.5 NUMERICAL ANALYSIS

4.5.1 INTRODUCTION

A quantitative technique employing cluster analysis was applied to several data sets to explore the relationships, if any, between sample sites and pollen composition of the drillholes.

It is well established from a number of palynological investigations, for example Birks and Birks (1980) and Luly, Sluiter and Kershaw (1980), that cluster analysis employed for straitigraphic correlative purposes should incorporate a stratigraphic constraint. This allows only stratigraphically adjacent or derived sample groups to fuse. Then, the breaks between cluster groups can be used to locate the best positions for zone boundaries on pollen diagrams. The zones thus established for individual drillholes, are then correlated with other drillholes in order to define regional zones. Pollen zones are usually visually matched or correlated although a number of numerical methods

(Gordon and Birks 1974) have been used with success.

As the two cluster programmes employed had no provision for stratigraphic constraint, sample cluster anomalies were expected. However, the programmes were run, using different similarity / dissimilarity measures and methods of cluster linkage, to determine if any broad but recurrent patterns were evident. Any such patterns would thus be of value in zoning of pollen diagrams and thereby the subdivision of the Morley Coal Measures.

The first of the two clustering programs employed came from the MVSP suite of computer programs designed for a variety of multivariate analysis. This program performed average linkage cluster analysis using the Canberra metric distance, a dissimilarity measure, and a weighted pair group method of cluster fusion. In one case the Spearman rank order dissimilarity correlation coefficient was used. The second method came from the PC-ORD suite of computer programs also designed for multivariate analysis of ecological data. This program performed hierarchial cluster analysis using squared euclidean distance, a dissimilarity measure that weighted the major pollen taxa more than the minor types, and Wards method of cluster fusion, a minimum variance technique of hierarchial clustering.

4.5.2 MVSP CLUSTERING ANALYSIS

In this program three sets of pollen data were investigated. All were derived from Pollen Sum 2 data and were thus inferred to be anemophilous pollen and therefore representative of regional pollen rain. The data sets used were:

(1) *Phyllocladidites mawsonii*, clustered over all drillholes combined.

(2) *Podocarpidites cf. ellipticus* and *Podocarpidites marwickii* clustered over (a) all drillholes combined and (b) clustered over individual drillholes.

(3) Anemophilous group clustered over (a) all drillholes combined and

(b) clustered over individual drillholes.

4.5.2.1 *Phyllocladidites mawsonii* cluster analysis

P. mawsonii was one of the most commonly occurring and abundant pollen types encountered, however, there were significantly low counts in some samples. In the pollen diagrams there was no discernable pattern to this frequency fluctuation and for this reason was selected for cluster analysis to determine if significant trends were in fact present. The results of the cluster analysis were shown as a dendrogram (figure 19). The dissimilarity coefficient cut-off level defining the main clusters was chosen in order to highlight only the major groups. The samples belonging to these groups are shown in Figure 20. It is evident that many samples grouped were stratigraphically incompatible and in terms of the zonation established in section 4.4 no satisfactory correlation could be made using the cluster groups.

4.5.2.2 *P. cf. Ellipticus* and *P. marwickii* Cluster Analysis

The importance of these two species lies with the pioneering biostratigraphical scheme established by Couper (1964) in which they played major roles (see chapter 3). Although the scheme has been refuted in this study, it was decided to investigate the abundance characteristics of the two species by cluster analysis. The merit of this analysis, was of course, controlled by the limitations imposed by the absence of a stratigraphic constraint. The analysis was carried out using two sets of data. One consisted of the data for the two species from all drillholes combined, while the other consisted of data clustered for individual holes. The dendrogram for the analysis of all drillholes combined is presented in Figure 21. The dissimilarity coefficient cut-off level defining the cluster groups was selected in order to highlight the major groups (shown in Fig 22). A vague group was traced through drillholes 382, 335, 364 and 336 (group 1, Fig 22), however it lacked consistency of position relative to the zonation established in section 4.3 and included a significant number of stratigraphically incompatible samples clusters. No other patterns of significance were evident.

The analysis where individual drillholes were clustered produced equally inconclusive results. The dendrograms for the eight drillholes are produced in Figure 23. The cut-off level defining the main clusters was based on a dissimilarity coefficient of between 0.5 and 0.65. The major groups, shown in Figure 24, revealed few consistent patterns. While some groups, such as those in drillholes 347 and 375, contained groups agreeing with the zonation, the remaining drillholes contained stratigraphically incompatible grouping of samples. Generally, there appeared to be no consistent or valid cluster grouping through the drillhole sequence, however, a vague stratigraphically orientated grouping did seem to exist. It is possible that given a cluster program containing a stratigraphical constraint, useful results could be obtained.

4.5.2.3 Anemophilous Group Cluster Analysis

This group of pollen was selected for cluster analysis in view of its importance and use as regional paleo-vegetation indicators. The group was analysed in similar fashion to the groups above; it was first clustered over all drillholes combined, and secondly over individual drillholes.

The dendrogram for the cluster analysis of all drillholes combined is presented in Figure 25, the cut-off level defining the five main cluster groups was based on a dissimilarity coefficient of 0.5, the arrangement of these groups is shown in Figure 26. The results were again, inconclusive with no significant group defined. Six holes contained stratigraphically incompatible sample combinations. Of the remaining two holes, drillhole 347 had all its samples with the exception of the lower most, clustered as one group. In view of the zonation established in section 4.4 this grouping was considered dubious and discounted. Drillhole 336 had two sample groups with all samples stratigraphically compatible, the groups falling within the framework of the zonation established in section 4.4. As it is the only hole with this compatibility, it is difficult to draw conclusions with respect to its use for zonal purposes.

Although no significant groups were evident in this analysis it was apparent that group 1 (Fig 26), while containing a number of samples from lower down in each hole, had a persistent grouping of two or more samples in the upper region of all drillholes except drillhole 382 and 387. These groups fell within the Lower Unzoned Interval and Interzone 1 (section 4.4) and may reflect a genuine zone. Verification of this feature can, in all likelihood, only be determined by employing a cluster program incorporating a stratigraphical constraint.

The dendrograms for the cluster analysis of the Anemophilous group over individual drillholes are presented in Figure 27, with the main cluster groups shown in Figure 28 - the dissimilarity coefficient cut-off level defined major clusters only. The results were inconclusive, with no consistent groups present and all significant groups included stratigraphically incompatible samples.

4.5.3 PC-ORD CLUSTERING RESULTS

Two cluster analyses were carried out using this program. The first clustered data from all drillholes combined using Pollen Sum 1 data. The second analysis clustered data in individual drillholes also using Pollen Sum 1 data.

The first method involving clustering over the combined drillhole data set yielded inconclusive results. Vague groups were apparent between one or two holes but no consistent grouping could be detected throughout the drillhole sequence. Stratigraphically incompatible sample combinations were common. An uncertain grouping was apparent in the upper region of five drillholes (group a, Fig 30) where a group of generally three or more samples were clustered together. However, these groups were incompatable with the zonation established in section 4.4 and included a number of stratigraphically incompatible samples. In order to resolve this possible group, clustering needs to be carried out employing a stratigraphical constraint. The dendrogram for this analysis is shown in Figure 29. The dissimilarity coefficient cut-off level of 9.6 to 9.9 was determined to define the four main cluster groups.

The second cluster analysis involved clustering in individual drillholes. The dendrogram for the analysis is presented in Figure 31, with the cluster group positions in drillholes shown in Figure 32a-i. The dissimilarity coefficient cut-off level in each dendrogram was selected to define only major groups. The results were inconclusive with no consistent clusters groups and although some groups contained up to six samples in stratigraphic succession they also contained other stratigraphically incompatible samples. The major parts of these groups were not always compatible with the zonation established in section 4.4.

4.6 NUMERICAL ANALYSIS DISCUSSION

It was evident that while the results from both types of cluster analysis were essentially inconclusive, they did indicate that, although vague, a broad stratigraphically orientated grouping appeared to exist in some drillholes. These groups were not positive but indicated that:

(1) Groups based on pollen composition similarities may exist and hence provide more information for zonation, and

(2) The clustering programs need to be refined in order to increase the resolution of the groupings. This can, in all practicality be achieved by implementation of a stratigraphic constraint which allows only adjacent samples or derived sample groups to be clustered. If this can be achieved the results may prove useful in providing zonal criteria for subdivision of the Morley Coal Measures.

4.7 RATIO ANALYSIS OF SELECTED TAXA

This analysis was undertaken to investigate the potential of unusually high frequencies of selected pollen types for use in subdividing the Morley formation (following Martin 1984). In order to give precision to the meaning of "high frequencies" and to isolate the selected taxa from other features of the assemblages, ratios were constructed and a cut-off point chosen empirically to define the ratios. The pollen types selected were:

(1) *Phyllocladidites mawsonii*, as a ratio of total gymnosperms.

(2) *Microcachryidites antarcticus*, as a ratio of total gymnosperms.

(3) *Tricolpites gillii*, as a ratio of total angiosperms.

(4) *Nothofagus kaitangata*, as a ratio of total angiosperms.

The application of the ratio analysis to the zoning of the Morley formation required the high and low ratio groups - delineated by the cut-off levels, to have some degree of correlation over part or all of the drillhole sequence. Although the majority of the pollen types showed high ratios throughout the drillhole sequence (Figure 33a-d) the distribution of these ratios were generally irregular and patterns difficult to detect. Within the limits of the zonation established in section 4.4, the high and low ratio groups of all four pollen types revealed no discernable correlation patterns. This was shown by:

(1) High ratios of *N. kaitangata* occurring in the lower most samples of drillhole 375 and 387, and near the top of drillholes 382, 335, and 336. This pattern was incompatible with coal seam correlation.

(2) High ratios of *M. antarcticus* occurring at the top and bottom of drillhole 382, throughout drillhole 335, and absent in drillholes 343, 387, and 364. This pattern was also incompatible with coal seam correlation.

(3) The high ratio group of *T. gillii*, while occurring in the six lower samples of drillhole 375 had no regularity in any of the remaining drillholes.

In view of such discrepancies high ratios of *P. mawsonii*, *T. gillii*, *M. antarcticus*, and *N. kaitangata* were deemed to be of no value in the zoning of the Morley formation.

4.8 CONCLUSIONS

Three quantitative procedures were applied in an attempt to subdivide the Morley formation into units suitable for coal seam correlation. These procedures were:

(1) Pollen diagram zonation based on relative abundance patterns of selected taxa and groups of taxa.

(2) Pollen diagram zonation employing the numerical method of cluster analysis.

(3) A technique involving ratio values for selected taxa having unusually high abundance values.

The first method was successful in providing a basis for subdivision while the remaining two methods proved largely unproductive.

Method (1) employed procedures based on conventional pollen diagram zonation and utilized the consistent patterns of selected taxa and groups of taxa that could be traced with reasonable certainty throughout all or most of the drillholes in the project. Due to the sampling restrictions and geological complications such as folding, faulting and facies changes which operated during and after the deposition of the Morley formation, not all patterns showed up clearly in all holes. Examples were drillhole 347, located centrally in the Ohai depositional basin (Figure 5) but containing only a short sequence of the formation, and drillhole 375, located centrally in the Mossbank depositional basin (Figure 5) in which locations for several of the zonal patterns were subjective. Resolution of the zonal scheme was limited by the sample interval. The purpose of the analysis was not to define a rigid zonation, but to distinguish patterns that appeared consistent within the drillholes in the study area. The resolution of these patterns will undoubtably be refined with further palynological work. The zones defined by the scheme were consistent with geological models for the Morley formation, interpretation of the zones suggest that:

(1) During the early part of the Morley formation, rates of sedimentation were similar in both the Ohai and Mossbank basins. This is indicated by the relatively uniform thickness of the Lower Unzoned Interval and Interzone 1 (Figure 13).

(2) The significant increase in thickness of Interzone 2 and an associated increase in the thickness of the coal seams contained therein, of drillholes 382, 335, 364, 336 and 343 was inferred to be indicative of a deeper, rapidly subsiding part of the basin.

(3) It was difficult to draw accurate conclusions from the Upper Unzoned Interval due to it's upper contact being the Beaumont-Morley formation erosional contact. It was clear that significant parts of

the upper Morley formation were removed as a result of this hiatus (Sykes 1984, Bowman et al 1987).

(4) The relatively thinner clastic units which occurred in drillhole 375 (located in the Mossbank basin) probably reflected a depositional basin unlike the Ohai basin in that it was sheltered from major source areas to the north. This is in keeping with the concept of paleo-highs discussed in section 4.4.2.

The investigation of numerical analysis for zonal purposes was, in all practicality, unproductive. This was probably due to the absence of a stratigraphic constraint which allows only stratigraphically adjacent samples and derived sample groups to fuse. The results did however, indicate the presence of vague groups which suggested refinement of the procedure could produce helpful results in the zoning of pollen diagrams and thus the subdivision of the Morley formation.

The ratio analysis was investigated to determine whether the unusually high abundance of some taxa had stratigraphic application. The results suggest that this method was not applicable at Ohai. However, in light of the sampling restrictions discussed earlier it is possible that a closer sampling interval may reveal useful patterns.

CHAPTER 5

5.1 DIFFERENTIATION OF THE BEAUMONT AND MORLEY COAL MEASURES ON PALYNOLOGICAL GROUNDS

The boundary separating the Morley Coal Measures from the overlying Upper Eocene Beaumont Coal Measures is well established to be an unconformity surface on the basis of both palynological work (Couper in Suggate and Couper, 1952; in Bowen 1964, Pocknall 1984, Raine 1986), and on stratigraphic and structural evidence presented by Bowen (1964). Palynological work of this project also firmly supports the existence of a significant hiatus. Recognition of the unconformity surface has major importance with respect to the correlation of seams within the Morley Coal Measures. Detecting this surface, especially in drillholes, has often proven problematical. However, this project has shown that, given core that span the unconformity surface, the Morley and Beaumont Coal Measures are readily distinguishable on palynological grounds. Discrimination between the two formations is based on the distinctive spore and pollen assemblages unique to each formation. The Morley Coal Measures contain taxa with ranges not extending above the Haumurian. Examples are *Tricolpites lilliei*, *Proteacidites subpalisadus*, *Nothofagus kaitangata*, *Trilites morleyi*, and *Baculatisporites comaumensis* (shown in the photographic plates). The Beaumont Coal Measures on the other hand, contain taxa whose first appearances range from the Teurian to Bortonian. Examples of these species are: *Myricipites harrisii*, *Cupanieidites orthoteichus*, *Myrtaceidites parvus*, *Nothofagus matauraensis*, *Nothofagus brachyspinulosa*, and *Elytranthe striatus*. Because the Beaumont Coal Measures are economically insignificant, zonation was not attempted; hence the purpose for distinguishing the formation was purely to delineate the upper boundary of the Morley Formation. In this respect assemblage slides from samples from the upper parts of the sequence were given preliminary scans before accurate counting began to establish whether they belonged to Morley or Beaumont sequences. If positive identifications of Tertiary taxa were made further analysis was terminated and the slide abandoned. In many cases significant quantities significant quantities of reworked Morley Coal Measure taxa were present, indicating erosion or reworking of the older unit was occurring during deposition of the Beaumont Coal Measures.

The precise stratigraphic location of the unconformity surface, believed to include the Cretaceous/Tertiary boundary, was not defined in this project, this would have required considerable resampling in order to determine its true position. The boundary was instead located within the framework of the sampling program which consisted of an interval of approximately 10 metres between samples. This degree of resolution was, nevertheless, adequate for the purposes of the zonation of the Morley Coal Measures proposed in this project and also clearly draw attention to errors in earlier attempts at delineating the Beaumont/Morley boundary using lithological criteria. The position of the boundary determined by palynological evidence from this project and by earlier attempts using only lithological criteria is shown in Figure 34. It is evident that there is considerable error in the boundary position using lithological criteria only. Drillholes 387, 382, 336, 335, and 384 graphically demonstrate the margins of error which range from 19 metres in drillhole 382 to 88 metres in drillhole 384. The significance of such error cannot be over stated. The correct position for the boundary could not be determined in drillholes 347 and 343 due to core absence. The Morley Formation in this case extends to the top of the cored sequence. Drillholes 364 and 375 already had accurate locations for the Beaumont/Morley boundary determined by palynological analysis (Raine 1986) carried out prior to this project. In these drillholes the boundary position has been refined as a consequence of the present study.

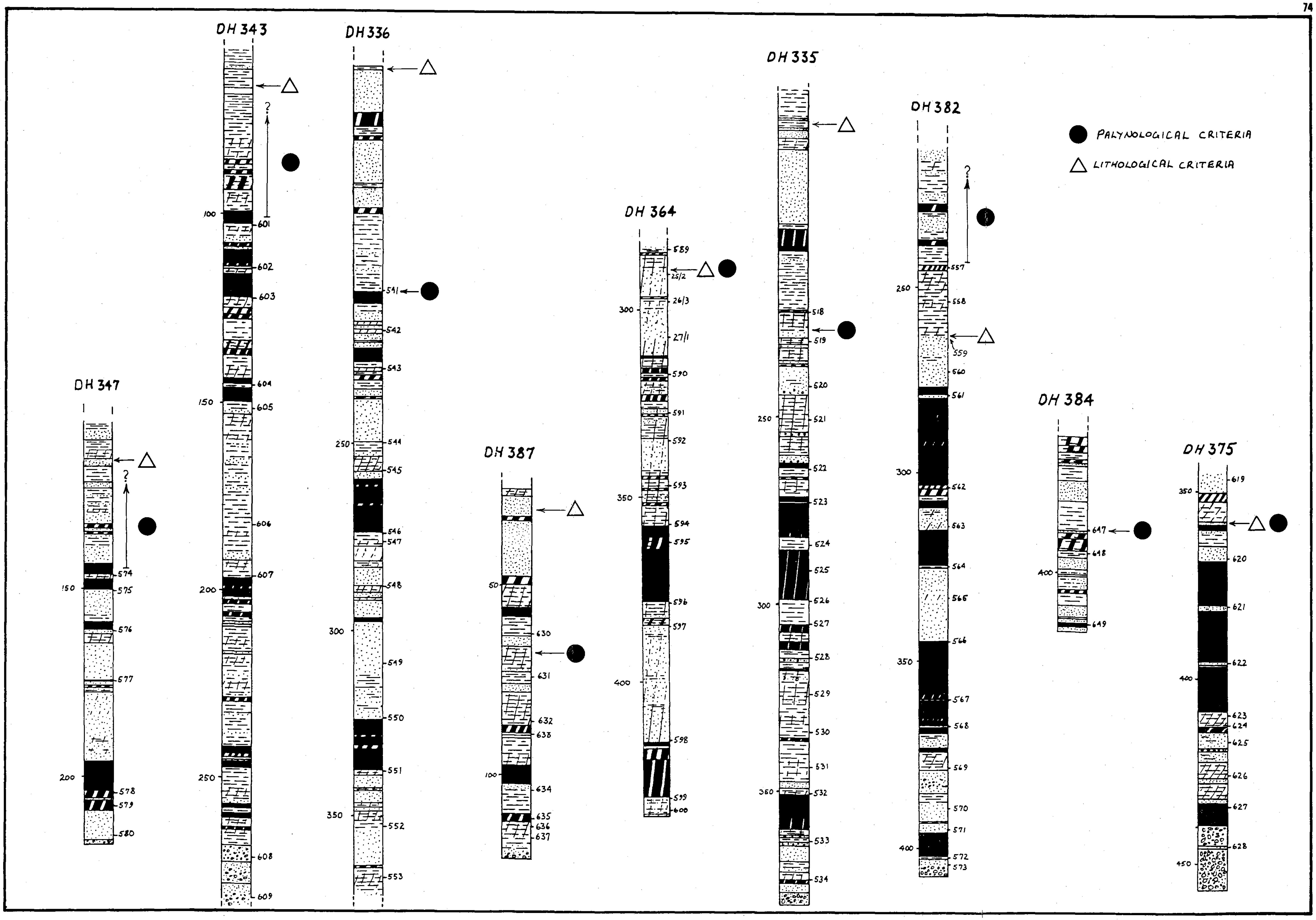


Figure 34 : Drillhole logs showing the Beaumont/Morley contact determined by palynological evidence from this project and by earlier attempts using lithological criteria.

CHAPTER 6

TAXONOMIC NOTES

Some pollen and spores frequently identified in assemblage slides from samples of the Morley Coal Measures, could not be assigned to any known taxa. For these, informal names were introduced. It is likely that more intensive study of the taxa belonging to these informal classifications would show that, in some cases, groups of similar pollen or spore types are represented rather than discrete species. The following remarks are intended to highlight and explain the usage and implications of the major informal pollen and spore types.

ANGIOSPERMS

Tricolpites pachyexinus Couper 1953

1953 *Tricolpites pachyexinus* Couper: p62, pl.8, Fig.120,121.

Couper's description of this species maintains the exine to be "..very thick, 2.5 - 3.0µm, psilate" with a polar size range of 27-(35)-43µm. However, many grains attributable to this species were encountered with: (a) exines in the range 1.3 - 2.0µm, (b) finely granular (LO pattern) to psilate sexine, and (c) minimum polar dimensions of 20 - 25µm. It is therefore suggested that Couper's specifications may need amending to accommodate such differences. This suggestion is endorsed with the remark by Dettman and Playford (1968) that Australian grains referable to *T. pachyexinus* Couper are somewhat smaller (have an equatorial diameter of 20-(24)-31µm) and have a generally thinner exine (1.5 - 3.0µm) than those described by Couper (1953, 1960). Although the dimensions stated by Dettman and Playford are equatorial it is likely that the polar dimensions are also smaller than those indicated in the original description.

Tricolpites sp. E

Grains referred to by this name, while not overly abundant, warrant discussion due to their similarities with *Tricolpites pachyexinus* (Couper 1953) and *Tricolpites secarius* (McIntyre 1965). In general the grains have a polar dimension of 15-24µm, copli extending almost to the pole, an exine thickness of 1.0-1.5µm, a fine reticulate or granular surface texture (LO pattern) that is difficult to distinguish due to the small grain size, and slightly convex to convex sides. These attributes, though somewhat marginal, are compatible with the dimensions suggested for *T. pachyexinus* discussed above. These grains also share similarities with *T. secarius*, which although having a range commencing in the Teurian, has greater compatibility. If these grains are in fact *T. secarius*, then the range of this species must be extended into the Cretaceous, however until more of these grains are examined their true affinity must remain in question.

Ticolpites sp. B

Free, isopolar, prolate, tricolpate, colpi long and narrow, exine 1-1.8µm thick, sexine distinctly and finely reticulate.

Equorial diameter: 17-30µm

Remarks: Grains of this type were identified in both Cretaceous and Eocene material.

Tricolpites sp. C

Free, isopolar, prolate, tricolpate, colpi long and narrow, extending almost to poles, exine 1.8-2µm, sexine and nexine not easily distinguished, sexine tectate, finely granular; granules very small.

Equatorial diameter: 48µm

Polar diameter: 29µm

Tricolpites sp. D

Free, isopolar, prolate-spheroidal, colpi long, nexine 0.5-1µm, sexine 1-1.5µm, finely reticulate, lumina less than 1µm wide.

Equatorial diameter: 21-33µm

Polar diameter: 18-25µm

Tricolpites sp. F

Free, isoploar, prolate, tricolpate, colpi long and narrow, reaching almost to poles, exine 0.9-1.5µm, sexine scabrate to finely granular (faint LO pattern).

Equatorial diameter: 15-30µm

Remarks: Grains of this type were identified in both Cretaceous and Eocene material.

Tricolpites sp. G

Free, isopolar, prolate to spheroidal, tricolpate, colpi narrow, extending almost to poles, exine 1-2µm, sexine clearly reticulate ; lumina relatively large (1-1.7µm wide), and generally coarsen in equatorial regions.

Equatorial diameter: 15-24µm

Tricolpites sp. J

Free, isopolar, prolate to per-prolate, colpi long, nexine 0.5-1um, sexine 1-1.5µm with fused clavae forming a fine reticulum ; lumina less than 1µm wide.

Equatorial diameter: 30-35µm

Polar diameter: 13-20µm

Remarks: This grain is similar in many respects to *Ticolpites sp. D*, however it is always distinctly prolate to per-prolate.

Tricolpites sp. K

This grain type was not stratigraphically or otherwise important but probably has some regional significance due to its probable affinity with a similar form - *Tricolpites sp. K*- found and described in the Cretaceous Kaitangata Coal Measures by Browne (1986). The species letter designation here follows that of Browne. These grains were characterised by short, narrow colpi (nowhere seen to extend more than half way to the poles), is thin walled (0.8 - 1.5µm), has a distinct granular texture, has a polar range of 17 - 35µm, and is semi-fossaperture.

Tricolpites sp. L

Free, isopolar, prolate to per-prolate, colpi long and narrow, reaching almost to poles, exine 2-2.5µm, densely spaced granules ;

granules 2μm high and 2.5μm diameter at base.

Equatorial diameter: 31μm

Polar diameter: 19μm

Tricolpites sp. M

Free, isopolar, spheroidal, colpi long and broad, nexine difficult to detect, sexine 1.5-2μm thick, baculate/clavate forming an excellent reticulum ; lumina 2-3μm at edge of grain, decreasing to 0.5μm in central regions, muri thin.

Polar diameter: 30μm

Tricolpites sp. N

Free, isopolar, prolate, colpi long, nexine lum thick, sexine 1.2-1.6μm thick, probably baculate and supratectal, but possibly only supratectal bacules, forming indistinct reticulum.

Equatorial diameter: 30μm

Polar diameter: 23μm

Tricolpites sp. O

Free, isopolar, spheroidal to oblate, colpi long and thin, exine 0.8-1.2μm thick, finely and sometimes indistinctly granular.

Equatorial diameter: 21μm

Polar diameter: 21μm

Tricolpites sp. P

Free, isopolar, spheroidal, colpi short and broad, nexine difficult to distinguish, sexine 2.5-4μm, spinulate ; spines 2-3μm long and 0.5-1μm diameter at base, 1.7-2.5μm apart.

Polar diameter: 41μm

Tricoplites sp. Q

Free, isopolar, spheroidal to prolate, colpi long and narrow, nexine 0.5-1μm thick, sexine 1-1.5μm thick, coarsely baculate forming a coarse reticulum; lumina 1.5-2.2μm wide, muri 1.3μm.

Equatorial diameter: 24-30μm

Polar diameter: 18-20μm

Tricolpites sp. W

Free, isopolar, spheroidal, colpi distinctly smooth and "scalloped" in shape, 6µm wide, exine 1-1.5µm thick, sparsely echinate ; echinae 1µm high.

Polar diameter: 22-24µm

Tricolpites sp. Y

Free, isopolar, prolate, colpi long and narrow, nexine 0.5µm thick, sexine 1.5-1.8µm, baculate ; arranged in a distinct linear pattern giving in surface view a characteristic striated appearance.

Equatorial diameter: 25-30µm

Polar diameter: 18-24µm

Tricolpites sp. Z

Free, isopolar, spheroidal, colpi short (13µm deep) and broad (10µm), exine 1.5-2µm thick, verrucate; verrucae 3.5µm diameter at base, 0.5µm high.

Polar diameter: 30-42µm

Tricolporites sp. B

Free, isopolar, spheroidal to prolate, tricolporate, colpi long, ora 1-3µm wide, up to 4µm long, exine 1.5-2µm thick, exine and sexine of similar thickness, sexine baculate/clavate forming a fine reticulum ; lumina 0.5-1.3µm.

Equatorial diameter: 20-32µm

Polar diameter: 18-25µm

Tricolporites sp. C

Free, anisopolar, prolate to per-prolate, tricolporate, colpi long and narrow, ora difficult to measure, approx. 2µm diameter, exine thin (1-3µm), sexine finely granular; granules sometimes indistinct.

Equatorial diameter: 19-27µm

Polar diameter: 15-18µm

Tricolporites sp. D

Free, anisopolar, spheroidal, tricolporat, colpi long, ora difficult to measure - approx. 1-1.5µm diameter, exine thin (0.8-1.5µm), finely papillate; papillae 0.5x0.5µm, spaced 2-3µm apart.

Equatorial diameter:20-25µm

Tetracolpites sp. O

Free, isopolar, tetracolpate, colpi short (5µm deep) and narrow, exine 1.3-2.2µm thick, sexine baculate/clavate, forming a fine reticulum.

Polar diameter: 23-35µm

Remarks: This grain is possibly tetracolporate, however poor preservation of grains made this difficult to determine.

Liliacidites cf. variegatus

1953 *Liliacidites variegatus* Couper: p56, pl.7, fig. 98,99.
Some confusion still exists in the literature regarding the distinction between *Liliacidites variegatus* (Couper 1953) and *Liliacidites intermedius* (Couper 1953), and their respective age ranges. While Couper (1953) appeared to make a clear distinction between them, it was apparent both from observations made in this project, and from Pocknall and Mildenhall (1984) that some specimens have features intermediate between the two species, suggesting that *L. variegtus* and *L. intermedius* represent end members in a morphological range of one species. Pocknall and Mildenhall also point out that Couper (1960) had similar ranges for the two species which further emphasises the similarity and difficulty in distinguishing between them. Raine (in Pocknall and Mildenhall 1984) suggested that most late Cretaceous and early Tertiary specimens are more like *L. intermedius* with a clearly defined and abrupt change in size of the reticulum between the equatorial and polar region of the grain. Observations made in this thesis tend not to agree with this as the majority of grains identifiable as either *L. variegatus* or *L. intermedius* had (a) grain lengths of 20-40µm, and (b) exines 1.0-1.5µm thick. Although many of these grains exhibited a change in reticulum size between equatorial and polar regions the change was not often abrupt. In terms of Couper's (1953) description, the grain length and exine thickness disallow these grains to be classed as *L. intermedius*. It is clear that until further research is conducted, confussion will remain over the distinction or "non-distinction" between the two species.

Liliacidites sp. A

Free, anisopolar, bilateral, monsulcate, sulcus long and narrow, grain sub-spheroidal, exine thin (1-1.5µm), sexine thicker than nexine, baculate, forming a clear, distinctive reticulum ; lumina 2-3µm wide, muri distinctive; 0.5-1µm thick with a "beaded" appearance.

Dimensions: 25-30µm long
18-25µm wide

Liliacidites sp. D

Free, anisopolar, bilateral, monosulcate, sulcus long and broad, grain sub-spheroidal, exine 1.5-2µm thick, sexine pilate, with fused heads, forming a clear reticulum ; lumina 1-3µm wide, muri 0.5µm thick.

Dimensions: 30-36µm long
23-29µm wide

Monosulcites aff. minimus Couper (1953)

1947 *Monosulcites minimus* n.sp Cookson: p135, pl.15, fig 47-50.

1953 *Monosulcites aff. minimus* (n.sp) Couper: p65, pl.8, fig 130,131.

Cookson describes the species *M. minimus* as having an exine about 2µm thick. No grains similar to *M. minimus* were observed in this project to possess exines thicker than 1.3µm, although they were in every other respect almost identical. Couper (1953) considered the two species *M. minmius* and *M. maxima* (of Cookson 1947) to represent a form genus diagnosed amoung other things as having a variable exine. He went on to describe and figure a new species (after Cookson) *Monosulcites aff. minimus*, which was more elongate and possessed a thinner exine than *M. minimus*. This type species is adopted in this thesis.

Monosulcites sp. A

Free, anisopolar, bilateral, monosulcate, sulcus long and thin, grain prolate, exine approx. 1-1.5µm thick, sexine granulate ; granules rounded, 1.3µm at base and 1µm high.

Dimensions: 30µm long
18µm wide

Monosulcites sp. B

Free, anisopilar, bilateral, monsulcate, sulcus long and narrow, grain spheroidal to sub-spheroidal, exine 2-4μm thick, nexine difficult to measure, sexine thick, granulate to verrucate ; 4-7μm at base, 2-3.5μm high. Inner region surrounding sulcus has reduced sculpture.

Dimensions: 25-30μm long
20-25μm wide

Monosulcites sp. C

Free, anisopolar, bilateral, monosulcate, sulcus long and broad, grain spheroidal, exine 2-3.5μm thick, sexine baculate/clavate (some parts appear supratectal), with granular surface texture, granules 1-2μm high, 1-3μm diameter at base.

Dimensions: 26-40μm long
20-30μm wide

Monosulcites sp. D

Free, anisopolar, bilateral, monosulcate, sulcus long and broad, grain sub-spheroidal to prolate, exine approx. 2μm thick, nexine difficult to measure, sexine echinate ; echinae small (less than 1μm high) and densely spaced.

Dimensions: 31 ..?μm long (a similar grain 70μm was observed)
25 ..?μm wide

Monosulcites sp. E

Free, anisopolar, bilateral, monosulcate (possibly tricolpate), sulcus long and narrow, grain sub-spheroidal to prolate, exine difficult to measure, sexine distinctly striated, striations have vague "beaded appearance".

Dimensions: 35μm long
20μm wide

Monosulcites sp. H

Free, anisopolar, bilateral, monsulcate, sulcus narrow with thick granular lips, grain spheroidal, nexine 1-1.5μm thick, sexine 1.5-3μm thick, finely granular with clear LO pattern.

Dimensions: 35-40μm long

Monosulcites sp. J

Free, anisopolar, bilateral, monsulcate, sulcus long and broad, grain spheroidal to sub-spheroidal, exine 3-4µm thick, sexine 2-3µm thick with gemma type sculpture; 2-3.5µm diameter at base, 2µm in height, and up to 5.5µm apart.

Dimensions: 40-50µm long
30-35µm wide

Monosulcites sp. K

Free, anisopolar, bilateral, monosulcate, sulcus long and narrow, grain spheroidal to prolate, exine 2-4µm thick, nexine less than 1µm thick, sexine 2-3µm thick with spinules ; 0.8-1.3µm diameter at base, and 1.5-2.2µm high.

Dimensions: 22-30µm long
14-20µm wide

Monosulcites sp. M

Free, anisopolar, bilateral, monsulcate, sulcus long and narrow, grain plano-convex in profile, exine 3um thick, surface texture faintly granular to psilate with reminiscent reticulation.

Dimensions: 38µm long
23µm wide

Monosulcites "subgranulatus"

The species name "subgranulatus" is used informally to describe abundant monosulcate pollen grains similar to *Monosulcites granulatus* Couper (1953). *M. subgranulatus* is distinctive because (a) it has a uniform, fine to very fine granular texture, and (b) it has a length of 19-37µm and a breadth of 15-27µm. These features clearly differentiate these grains from the larger, coarser textured species of *M. granulatus*.

Proteacidites sp. A

Free, isopolar, amb triangular with sides convex to straight, triorate, ora 3-5µm diameter with often ragged margins, exine thin (1.3-1.8µm), sexine finely reticulate.

Equatorial diameter: 25-30µm

Proteacidites sp. C

Free, isopolar, amb triangular, sides straight to slightly convex, triorate, ora 3-4µm diameter, exine 1.3 -2µm thick, surface texture appears finely granular.

Equatorial diameter: 25µm

Proteacidites sp. G

Free, isopolar, amb triangular, sides straight to slightly convex, triorate, ora 4-5µm diameter with smooth margins, exine 1.4µm thick, nexine thin, sexine distinctly granular ; granules have base diameter of 0.8-1.6µm, height of 0.5µm.

Equatorial diameter: 30-36µm

Proteacidites sp.

Abundant proteacidites type pollen are preserved in the Ohai sediments with many forms undoubtably representing undescribed taxa. This classification has been introduced to account for consistently occurring proteaceous grains possessing the following general characteristics: Triorate, isopolar, ora; circular, 3-6µm in diameter, sides; straight to slightly convex or concave between ora in polar view, exine; very thin, 1-2µm, sexine finely clavate - baculate forming a fine reticulum sometimes coarsening in central regions, (difficult to measure), equatorial diameter 19 - 30µm.

Beaupreadites sp.

Free, amb triangular with sides straight to slightly convex, apertures often colpoid and up to 14µm deep, exine 2-3µm thick, exine echinate ; echinae 1-2µm high, spaced 1-8µm apart.

Equatorial diameter: 30-38µm

GYMNOSPERMS

Podocarpidites sp A

This name was introduced to account for an abundance of podocarpaceous grains possessing generally consistent morphologic features, but was difficult to formally name. These grains were unlike

20-25µm), with a faint unveined reticulation. The furrow was granular and well developed. The corpus was broadly elliptical to circular in polar view, proximal cap granular, marginal ridge faint. The exine of the proximal cap is 1.0 - 2.0µm thick. It is possible that these grains are two bladdered forms of *Microcachryditіes antarcticus* (Cookson 1947) as the dimensions were generally similar, however, from the literature, it was apparent that the two bladdered forms were not overly common - as they were in the assemblage slides of this project.

Trichotomosulcites sp. A

Free, anisopolar to isopolar, trichotomosulcate, sulcus as in *Trichotomosulcites subgranulatus* Couper (1953), amb sub-triangular to sub-circular in polar view, sides convex, exine 1-2µm thick, sexine baculate/clavate forming a distinctive, fine, pitted reticulum.

Polar diameter: 15-23µm

SPORITES

Trilites morleyii Couper (1953)

1953. *Trilites morleyii* Couper, p30, pl.3, Fig.22.

Couper describes this species as having an equatorial diameter of 84-(92)-95µm. This is by general comparison a large spore and is usually readily identifiable, however, of the few spores firmly identified as *T. morleyii* none possessed an equatorial diameter within these limits. Instead equatorial diameters ranged from 50-70µm. Many of the spores 50-60µm in diameter were very much like *T. morleyii* but had marginal exine thickness's and may not in fact be *T. morleyii* at all. The remaing spores with diameters of 60-70µm were considered good examples of the species, therefore, it is suggested that Couper's size ranges may need revision.

Trilites ohaienesis Couper (1953)

1953 *Trilites ohaiensis* Couper, p30, pl.3, Fig.23.

The size range of this spore, as in *Trilites morleyii*, is suggested to also need revision. Grains identified as *T. Ohaiensis* in the

Trilites ohaienesis Couper (1953)

1953 *Trilites ohaiensis* Couper, p30, pl.3, Fig.23.

The size range of this spore, as in *Trilites morleyii*, is suggested to also need revision. Grains identified as *T. Ohaiensis* in the assemblage's of this thesis had an equatorial diameter of 60-70µm, however in the original description (Couper 1953) the size range was stated as 80-(88)-105µm (equatorial diameter). The spores identified as *T. ohaiensis* were considered accurate in all respects except for the equatorial diameter. In order to accommodate the spores with diameters of 60µm the original size range is suggested to need revision.

Baculatisporites cf. comaumensis

1953 *Trilites comaumensis* Cookson, p470, pl.2, fig.27,28.

1956 *Baculatisporites comaumensis* (Cookson) Potonie, p23.

1957 *Osmundacites comaumensis* (Cookson) Balme, p25, pl.4, fig.54-56.

1962 non *Osmundacites wellmanii* Couper: Pocock, p35, pl.1, fig.15.

1963 *Baculatisporites comaumensis* Dettman, p35, pl.3, fig. 22,23,4k.

This species is distinctive from *Osmundacites wellmanii* in having baculate and not granulate sculpture, however many of the grains encountered in this project have their sculptural elements arranged somewhat closer together than that indicated by Dettman (1963) and Cookson (1953).

Trilites sp. A

Free, anisopolar, trilete, laesurae short and narrow ending half way to amb, spore circular in polar view, exine 1.3µm, finely granular.

Equatorial diameter: 25-35µm

Trilites sp. D

Free. anisopolar, trilete, laesurae moderately long with prominent margins, extending almost to amb, spore circular in polar view, exine 1.5-3µm thick, finely granular.

Equatorial diameter: 40-45µm

Osmundacidites sp. A

Spores trilete, amb spherical, laesurae straight, extending three quarters the way to amb, has thickened margins, exine thin (1-1.3µm thick), finely granular (granules difficult to measure).

Equatorial diameter: 35-62µm

Stereisporites sp. A

Spores trilete, amb spherical to sub-triangular, with broadly rounded angles, laesurae straight and narrow, extending half way to amb, exine thin (1µm), distinctly but finely granular, with distal polar thickening extending half way to the amb.

Equatorial diameter: 28-35µm

Lycopodium sp. A

Spores trilete, plano-convex, amb sub-triangular to sub-circular, laesurae straight, extending to amb, gaping in inner regions, exine 1-1.5µm thick, smooth proximally, reticulate distally and equatorially ; reticulum variable, 1-7µm wide, muri thin, projecting up to 1.4µm high.

Equatorial diameter: apprx. 54µm

Lycopodium sp. B

Spores trilete, biconvex, amb sub-triangular to sub-circular, laesurae thick (2.2µm) and slightly contorted, extending to amb, exine thin (1.3µm), smooth to faintly granular proximally, and reticulate distally ; lumina 3-5µm wide in mid regions, reducing to 1-1.5µm wide on margins, muri thin and do not project upwards.

Equatorial diameter: 20-25µm

Polypodiidites cf. minimus

1960 *Polypodiidites minimus* n.sp Couper, p40, pl.1, fig 9,10.

The age range of this species is Kaiatan to Awamoan (Couper 1960), however, very similar grains were encountered not uncommonly in the Cretaceous material of this project. With the exception of scuplture which did not appear to be markedly reduced on the proximal face, these spores conform well with Couper's *P. minimus*. Due to the subjective nature of this feature it is suggested that the age range of Couper's new species *Polypodiidites minimus*, may extend into the Cretaceous.

Polypodiidites sp C

This classification was introduced to account for a sometimes abundant occurrence of spores attributable to the *Polypodiidites* genus. This grain consistently features an irregular, reduced verrucate sculpture (up to 6um across), a thin exine (less than 1.0μm), and grain dimensions; length: 24 - 32 μm, depth: 15 - 22μm. This sporotype was found only in Cretaceous material.

Polypodiidites sp. D

Free, anisopolar, bilateral, plano-convex to concavo-convex, ends well rounded, contact face concave to flat, monolete, laesurae about two thirds spore length, exine 1.5-2μm thick, sculpture sub-verrucate, very flat, less than 2μm diameter.

Dimensions: 40-55μm long
35-45μm wide

Verrucatosporites sp.

Free, anisoploar, bilateral, plano-convex, ends rounded, contact face concave, monolete, laesurae difficult to observe, exine 3-4μm thick, sculpture rounded to pointed verrucae, closley spaced ; verrucae 1-5μm diameter and 3-4μm high.

Dimensions: 28-34μm long
20-22μm wide

CONCLUSIONS

Within the Ohai Coalfield it has been well established that both correlation of coal seams and definition of the Beaumont/Morley boundary cannot be satisfactorily accomplished using solely lithological criteria. The reasons behind this failure rest with the complex structural nature of the coalfield which is characterised by dramatic thinning and splitting of seams, associated faulting and abrupt facies changes. On the other hand the distribution of pollen and spores, particularly anemophilous types, is not affected by many of these geological controls and thus becomes a powerful tool for coal seam correlation. This concept was first utilized by Couper (1964) who pioneered a palynological zonation for the Ohai Coalfield. However, the application of Couper's approach to data gathered in this latest study proved inconclusive with generally incompatible sample grouping. The scheme was refuted for four main reasons:

(1) The pollen counting technique employed by Couper did not follow conventional methods which advocate a minimum count for each slide of 150 grains. In 26% of Couper's samples grain counts fell below 150. These samples were considered to be statistically invalid and not representative of the sample population.

(2) The relative abundances of the key species in Couper's zonation (*Podocarpidites cf. ellipticus*, *Podocarpidites marwickii*, and *Phyllocladidites mawsonii*), as calculated in this study, were strongly at variance with Couper's data. Disparities included: (a) the abundance of *P. mawsonii* which, throughout the study area, was not as uniformly high as indicated by Couper, and (b) the abundances of *P. marwickii* and *P. cf. ellipticus* in a significant number of samples equaled or exceeded that of *P. mawsonii*. No sample in Couper's study yielded this result.

(3) The distinction between *P. cf. ellipticus* and *P. marwickii* was problematical due mainly to the overlap of the upper range of *P. ellipticus* and the lower range of *P. marwickii*. The poor preservation of many grains (corrosion and deformation) was also a limiting factor.

(4) Due to the structural complexity of the coalfield, Couper's data base consisting of two drillholes and two opencast pits, was deemed

inadequate for accurate palynological analysis. The two drillholes, d171 and d187, were 5 km apart and contained 8.2m and 117m of Morley Formation sediments respectively; both opencast pits were adjacent to d171 and were of limited strategic value as they worked only one seam each.

As an alternative to Couper's scheme, three quantitative procedures were investigated for use in subdividing the Morley Coal Measures. These consisted of:

(1) Pollen diagram zonation based on recurrent patterns of relative abundance of key taxa and groups of taxa through out the study area.

(2) Pollen diagram zonation employing the numerical method of cluster analysis, and

(3) A technique involving ratio values for selected taxa of recurrent and unusually high abundances.

The investigation of cluster analysis for zoning of pollen diagrams was, in all practicality, unproductive. This was probably due to the absence of a stratigraphical constraint which would have only allowed only adjacent samples or sample groups to fuse. The results did however, indicate the presence in some drillholes of vague groups which suggested refinement of the procedure could produce useful results in the zoning of pollen diagrams.

Results of the ratio analysis of taxa with unusually high abundance were also unproductive and suggested that this technique was not applicable at Ohai. However, it is possible that a sampling interval closer than the 10 metres used may reveal helpful patterns.

Technique (1) proved moderately successful in providing a basis for subdivision of the Morley Coal Measures into three pollen zones, two interzonal units and two bounding unzoned units. The subdivision, was, in descending order:

(1) The upper unzoned unit,

(2) The *Nothofagus kaitangata* Acme Zone,

(3) Interzone 1,

(4) The SPPA Assemblage Zone,

(5) Interzone 2,
(6) The *Tricolpites reticulatus* Acme Zone,
(7) The lower unzoned unit.

Of the three named pollen zones, two were based on the maximum abundance of a single species - *Nothofagus kaitangata* and *Tricolpites reticulatus* - and fall into the category of acme zones. The remaining zone was based on the distinctive association of the maximum frequency of the Sporites and Proteaceae groups and the podocarp *Phyllocladus paleogenicus*, and the minimum frequency of occurrence of the Anemophilous group and was thus clearly an assemblage zone.

The two interzones lacked any distinctive pollen signature and were defined on their intervening relationships between the three pollen zones. The upper unzoned unit was defined by the unconformable upper boundary of the Morley Coal Measures. The lower unzoned unit was similarly defined as the boundary of the Morley Coal Measures with the underlying New Brighton Conglomerate appeared unconformable in some parts of the coalfield and conformable in others.

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Appendix 1

RAW COUNT DATA, DH 364

SPECIES	UCP No. / DEPTH	600s 434.00	599 426.80	598s 411.30	597 381.50	596s 375.40	595s 358.00	594s 353.80	593s 343.55	592 332.30	591s 323.85	590s 313.60	L12727/1 305.74	L12726/3 296.53	L12725/2 287.89
SPORITES															
Peromonolites bowenii			5		1		3	1		2	4			5	
Cyathidites minor		16	6	20	18	24	9	5	10	28	8	13	9	34	15
C. australis		2													
Baculatisporites comaumensis		1	2	2	14	5	4			3	1		2	3	4
Osmundacidites wellmanii		4	6	4	12	3		1	5	8				5	2
Polypodiidites cf. minimus		1	1				2				1				
P. species B			2											1	
P. species C				3	1		1		1					15	
P. species D									1	1				6	1
Laevigatosporites ovatus		31	20	31	56	37	28	5	30	15	30	31	35	58	47
L. major		8			3	2		1							
Clavifera triplex		1	2		1		4	4	1	1	1	3		3	1
C. rudis			1				1	1							
Gleicheniidites circinidites		1			1		6			4		5	4	14	11
Trilites species A			2			1				4	1	1		1	
T. species D										1					
T. verrucatus		2			2	1	16	1		4	1	2	1	5	6
T. ohaiensis													1		
T. morleyi							1			5	3				
T. fragilis							1				1				
T. sinuatus														1	
T. cf. tuberculiformis						1	1								
T. sp			2	1	2	1									
Ceratosporites equalis				1		1	1				1	1	1	7	
Ceratosporites sp			1					1					1	4	2
L. sp (fastigiatum volubile grp)		3	7		1	1	2	2	2	5	8	1	13	20	5
L. fastigoides		1					1				1		1	5	2
Stereisporites antiquasporites			3	1			1			2			1	11	
S. regium				1					1				2	2	
S. sp		1													
Leptolepidites verrucatus											1		1		
Foveotriletes sp.		2					1							2	2
Biretisporites sp															3
Cingutriletes clavus											1	2	2		
Echinosporis sp														1	
GYMNOSPERMS															
Phyllocladidites mawsonii		12	50	5	16	16	52	153	21	82	14	115	38		22
Phyllocladus paleogenicus		2	8	4		5	5	4	5	4	2	6	6		8
Araucaricites australis						1			1		3	1		1	4
A. sp											3				
Podocarpidites cf. ellipticus		21	11	2	6	22	9	5	9	9	6	3	18	1	11
P. marwickii		7	8	2	5	1		16	2	6	12	5	24		7
P. major															1
P. sp A		7	5		3	6			6	2	4	5	6		1
P. sp		1	2	3	6	2	5	7	7	7	5		12		
Dacrydimites prae-cupressinoides										1					
Microcachrydites antarcticus		14	9	2	6	8	4	5	9	12	14	5	34	1	14
Tricholomosulcites subgranulatus		3	4	2	3	3	9	2	1	3	10	3	3	2	8
Ephedra notensis									1	1					
ANGIOSPERMS															
Tricolpites lilliei		3	1	4	3	2	2			1	4	3	7		2
T. reticulatus		27		2	6	2	2	1		2	4	1	1		2
T. gillii		27	43	11	38	51	30	4	58	10	42	10	10	7	22
T. sp Y												1			
T. verrucatus		1													1
Tricolpites sp			1						2						
T. species B			1	4	4	1	4		8	2	3	2			
T. species D		1													
T. species E			1	1			1								
T. species F		2		3	5	6	2		1		1				1
T. species J			1												
T. species K							1				2				
T. species M														1	
Tricolporate sp B				2		1			1						
T. species C					1	1	1		1			1			
Nothofagus kaitangata		20	17	1	20	10	5	23	29	9	19	11	1		10
Polycolpites clavatus		1	1				2		3		2				1
Inaperture species A				1	1										
L. variegatus		3	1				2				1	1			
L. sp					1	1					1				
Monosulcites granulatus							2								
M. sub-granulatus		3	2	6	7	6	10		6	6	7	4	1	7	11
M. aff. minima		15	10	3	3	11	4		6	3	13	3		11	8
M. species B		1										1		2	
M. species H		3	3		1	3	1		3		5				
M. species I										1	2			2	2
M. species M												1			
Proteacidites scaboratus												3	1		
P. cf. amolosexinus															1
P. retiformis			1			1			1					1	
P. sp		1	8	8	2	9	11	7	3	5	5	5	14	10	10
P. sub-palisadus		1													
P. species G				2				1				1			2
Gamberina rudata			1		1										
Beaupreadites sp						4	3		15	1	1			1	
Triorites minor											2				
Triorate/colpate sp H			1												
		250	250	132	250	250	250	250	250	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA. DH 382

SPECIES / UCP No	557s	558	559s	560s	561	562	563s	564	565s	566	567	568s	569	570	571s	572s	573s
DEPTH	243.92	254.36	262.90	273.20	278.98	303.94	314.40	324.40	333.41	344.26	359.75	369.18	378.40	389.64	395.70	402.27	404.30
SPORITES																	
Peromonolites bowenii						2	1		1	3	5	1	2	1			
Peromonolites sp			1														
Cyathidites minor	3	12	17	12	28	12	19	14	11	13	6	8	7	1	2	4	9
C. australis		4	1	3	5	5	4		2		2						
Baculatisporites comaumensis	9	7	8	1	3	1				1	1				4	4	1
B. sp							2	6	2	4	1	1	11		1		
Osmundacidites wellmanii	7	4	9	4	5	1	2	5	6	4	1	1	21	4	7	1	3
O. species A	11	5	4														
O. sp												1					
Polypodiidites cf. minimus		1						1			1		1				
P. species B			1			1	3									1	
P. species C	3			1	1	1	2	2	2	13		3	6	1			
Laevigatosporites ovatus	19	18	35	26	40	14	22	38	20	39	24	44	51	27	33	50	25
L. major	9	8	1	4	8	3	8	10	3	9	5	6	12	3	13	3	5
Clavifera triplex		3		1	1	1	1										
Gleicheniidites circinidites	1		4	5		4	6		1		5		2				
Trilites species A				1	2		2		1				1	4		1	2
T. species D				1	3	1											
T. verrucatus	2	6	4	2	2	4	2	4	5	3	4	1	3			1	
T. ohaiensis								1				1	2	1			
T. morleyi		1	1					1									
T. fragilis			4							1					1		
T. sinuatus							1										
Ceratosporites equalis	1				3				1					1			
Lycopodium fastigoides											1						
L. sp (fastigiatum volubile gp)		6	5	7	7	6	5		12	4	9	16	20	8	7	8	8
L. species A									1								
L. sp.												1					
Stereisporites antiquasporites	1		1	2	1	5	3	1		5	5	2	1	5	1	1	
S. species A											1						
S. sp		1															
Leptolepidites verrucatus							1				1						
Foramisporis cf. asymmetricus													2				
Cingutriletes clavus				1					1		3						
Kraeuselisporites majus															1		
Aequitriradites spinulosus				1													
Aequitriradites sp		1															
GYMNOSPERMS																	
Phyllocladidites mawsonii	12	30	10	20	20	51	38	13	21	24	28	18	3	20	6	6	2
Phyllocladus paleogenicus	3	3	3	3	1	10	14	3	9	5	12	29	1	8	3	5	11
Araucaricites australis		7	5	3	5	6	2	8	2		6	5	2	3	7	2	18
A. sp	5		2	2	3	1	2	2	2	1	7	4	2	6	4	2	9
Podocarpidites cf. ellipticus	20	12	19	10	13	13	2	9	5	9	11	8	1	12	12	11	18
P. marwickii	12	6	6	7	4	11	7	9	4	3	19	2		5	7	1	4
P. sp A	1	7	6	7	7	5	5	8	2		5	8		10	2	1	5
P. sp	7	7	2				3	3	2	1	2	1					
Microcacrhydites antarcticus	29	31	32	20	24	22	18	18	8	4	18	7	3	36	16	7	7
Trichotomosulcites subgranulatu	3	4	5	4	1	3	9	4	4	3	7	10		15	9	9	3
T. species A			1									1			1		
Ephedra notensis							1									1	
Dacrydium prae-cupressnoides			1														
ANGIOSPERMS																	
Tricolpites lilliei	10	13		6	10		1	4	2	1		1			1		8
T. reticulatus	6	4	3	2	9	2		1	2	5				22	47	1	1
T. gillii	10	14	16	24	16	16	18	41	21	31	25	18	22	20	14	42	33
T. pachyexinus							1					1			1	1	
T. verrucatus				1													
T. species B	7			5			3	6	8	5	1	3	1	5	6	4	3
T. species D			1														
T. species E							1			1			1	1			2
T. species F	1	1	2	3	1	1		2	4	10	2	2		3	1	4	2
T. species I														1			
T. species J								1			1						
T. species K			1					3	1				2		1	1	6

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T. species L	5																
T. species M									1								1
T. species T																	1
T. species U															2		
T. species V															1		
Tricolporate species B							2										1
T. species C		1	4			3				2							
T. species D														1	1		
Nothofagus kaitangata	45	20	4	38	3	5	4	15	5	7	4	6	4	1	14	30	22
Caryophyllidites polyoratus		1															
Polycolpites clavatus		1	1	2			1		44	3		1	6		1	2	3
Polyorate species A									1								
Liliacidites intermedius																	1
L. variegatus	1		1		1			1	4	1	1		1		1	2	2
Monosulcites granulatus		2	1	1			1	3	1	4	2	1	3	2		8	5
M. sub-granulatus	4	1	9	1	1	3	2	6	7	13	4	3	7	6	4	10	7
M. maxima	1			1			1	2		2			5		2		1
M. aff. minima					5	5		4			1	9	9	9	5	1	
M. species A		1											3				
M. species C													4				
M. species D							1										
M. species H								1		1	1	2	1		1	1	1
M. species I			3	1	2												
Proteacidites scaboratus				1	1	3	4		1	2	4	1		1		1	2
P. cf. amolosexinus			1				1									1	
P. retiformis			1		1		1						1				1
P. sp	1	7	14	12	11	26	20		17	12	11	21	23	6	8	17	14
P. palisadus											1						
P. sub-palisadus											2	1				2	1
P. species B																1	
P. species F																1	
P. species G						1			2				3		1		
Beaupreadites sp							1			1							
Triorites minor						1											
T. fragilis														1			
T. cf. fragilis															1		1
T. species A							1		1							1	1
T. species B	1			1		1											
Inaperture species A												1					
Triorate/colpate sp H					2		1										
	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA. DH 336

SPECIES	UCP No.: 556	555	554	553	552s	551	550s	549s	548	547	546s	545s	544s	543s	542s
	DEPTH : 397.00	388.45	379.00	367.30	353.30	337.20	323.76	309.69	288.80	277.96	273.70	258.69	249.74	230.11	219.80
SPORITES															
Peromonolites bowenii	0		3	4	1	6	2	4	1	7	1	3			
Cyathidites minor	0	5	1	1	2	1	12	13	7	8	10	7	6	1	8
C. australis	0					1		1		1					
Baculatisporites comaumensis	0	7	6	3	2			4		7	2			1	1
B. sp	0	8	5	5	3	1		3		9	7	4	8	1	1
Osmundacidites wellmanii	0	5	2	5	16	5	1	14	3	24	4		3	2	17
O. sp	0							1							
Polypodiidites cf. minimus	0	1	2				2			2	2		2		
P. minimus	0														
P. species A	0				3										
P. species B	0							1		2					
P. species C	0	2					72	5	3	3	4	2	1	1	
Laevigatosporites ovatus	0	22	14	35	30	23	31	31	23	26	60	21	31	33	28
L. major	0	1	1	9	6	4		4	5	2	12	3	9	8	4
Clavifera triplex	0					5				4			1	2	
Gleicheniidites circinidites	0			1	1	3	1			1	1	6	1	1	3
Trilites species A	0									4		1		1	1
T. species B	0											1			
T. species C	0														
T. verrucatus	0	1			2	4	3	5	4	2	2	2	24		
T. cf. verrucatus	0	2													
T. ohaiensis	0					1	1	1	2			1		1	
T. morleyi	0							4							
T. fragilis	0												3		
Ceratosporites equalis	0	1	1	2				1	1	2	1		1		
L. sp (fastigiatum volubile grp)	0	16	17	5	4	1	2	28	2	1	2			2	9
L. fastigoides	0					1									1
L. species A	0	5		1											
L. sp.	0	9	4	2				4							
Stereisporites antiquasporites	0	8	3	2	3	2	5	27		2		4			3
Cingutriletes clavus	0	4	5	1										1	
Leptolepidites verrucatus	0	1					1				1	1	1		
L. major	0						6					2	3		
Tetrad species A	0													1	
Foramisporis cf asymmetricus	0			1				1							
Foveotriletes sp.	0		1												
GYMNOSPERMS															
Phyllocladidites mawsonii	0	23	46	4	13	74	10	2	10	3	6	60	12	22	17
Phyllocladus paleogenicus	0	7	15	8	5	10	6	3	2		2	6		6	8
Araucaricites australis	0	1	2	4	6		2	1	7	5			13	1	3
A. sp	0	1	2	9	9	3	15	8	16	6	6	8	17	5	6
Podocarpidites cf. ellipticus	0	6	11	9	9	7	4		7	4	6	5	2	4	4
P. marwickii	0	2	7	5	3	9			4	4	4				6
P. major	0	1	1	5						1		1			
P. sp A	0	7	17	8	14	27	1	2	6	5	6	5	4	5	16
D. cf prae-cupressinoides	0	7				3	1				1	1			1
Microcachrydites antarcticus	0	3	1	13	20	13	7	5	33	23	19	18	26	15	35
Trichotomosulcites subgranulatus	0	20	16	29	12	13	2	2	7	4	5	8	11	2	5
T. species A	0	1			6				3			1	5		
Ephedra notensis	0					1									1
ANGIOSPERMS															
Tricolpites lilliei	0		2	4	8	4			1	1	4		6		
T. reticulatus	0	2	1	10	15	1	1	2	4	10	15	7	5	1	1
T. gillii	0	20	16	7	8	14	10	4	16	22	20	12	8	27	8
T. pachyexinus	0				1							1			
T. species B	0		3	5	1				6	4	2	8	1	6	1
T. species C	0				1					2					
T. species D	0		1										1		
T. species E	0			2	7					4	1	1			
T. species F	0			7	2	2	1	3	7	16	9	4	3	8	2
T. species G	0			2		1					1				
T. species I	0														
T. species J	0				2								1		

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T. species K	0				1				1	2					
T. species L	0								1		1				
T. species M	0											1	1		
T. species N	0														1
Tri/poly colpate sp 1	0					1									
Tricolporate sp C	0		1	1	1				4						
T. species D	0				1				1						
Elytranthe cf. striatus	0	1	1		2										
Tetracolporites species A	0				2	2			1						
Nothofagus kaitangata	0	3	3	20	2	3	4	2	21	7	9	16	21	56	9
Polycolpites clavatus	0	1			3		7		1	3	7	3		2	
Inaperture sp A	0		1		2		1						1		
Liliacidites intermedius	0								1						
L. variegatus	0	2		4	5		1	3	4	1	1				2
L. sp A	0	1							1						
L. sp B	0									1					
L. sp C	0				5		1								
L. sp	0								2			1			
Monosulcities granulatus'	0	2	1	7	4	3	10	12	13	4	2	5	6	1	4
M. sub-granulatus	0								2		1	6		9	1
M. maxima	0														
M. aff. minima	0	1			1		12	6	3	6	1	2	3	1	1
M. sp A	0	3		1					1					1	
M. sp B	0		1				3								
M. sp C	0										2				
M. sp E	0													1	
M. sp F	0														
M. sp G	0														
Proteacidites scaboratus	0						1				1	3	1		1
P. cf. amolosexinus	0				1			2							
P. sp	0	18	21	5	3		7	21	10	1	7	4	4	15	35
P. sub-palisadus	0		1	2	2	1		3				2		2	
P. sp A	0	1													
P. sp B	0	1						1							2
P. sp C	0							1							
P. sp D	0									1					
P. sp E	0														
P. sp	0	14	9	1			3	9		1			1		
Protea/Triorate sp I	0							2							
Gamberina rudata	0						1								
Beaupreadites sp	0							1		1	1	1			
Triorites minor	0	1	1					3	2		1				
T. fragilis	0												1		
T. cf. fragilis	0	2	2												
T. suboveolatus	0									1					
T. sp A	0		2											1	1
T. sp B	0								1					3	
T. sp S	0														
Triorate/colpate sp H	0			1	1	1						1	2		3
Quadraplanus brossus	0											1			
	0	250	250	250	250	250	250	250	250	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA, DH 347

SPECIES	UCP No.: 574s	575s	576	577s	578	579	580
	DEPTH : 145.60	150.00	160.65	174.85	205.15	208.20	216.40
SPORITES							
Peromonolites bowenii		1	3			1	0
Cyathidites minor	23	12	7	4	10	10	0
C. australis	5						0
Baculatisporites comaumensis	11	12				1	0
B. species A							0
B. sp	12	2			1		0
Osmundacidites wellmanii	15	9			1	3	0
P. species A				1			0
P. species B						1	0
P. species C		3			4	1	0
Laevigatosporites ovatus	31	29	18	24	27	16	0
L. major	25	3	1	10	4	3	0
Clavifera triplex			1	2			0
Gleicheniidites circinidites		4					0
Trilites species A		3	2	1			0
T. verrucatus	1	6			1	2	0
T. ohaiensis			1				0
T. morleyii		1					0
Ceratosporites equalis		2					0
L sp. (fastigiatum volubile grp)	11	6	5	3	15	12	0
L. fastigoides	2						0
L. sp A						1	
Stereisporites antiquasporites	2	12	6	1	6	14	0
Cingutriletes clavus		6		1			0
GYMNOSPERMS							0
Phyllocladidites mawsonii	17	12	59	51	20	33	0
Phyllocladus paleogenicus	11	11	13	12	25	28	0
Araucaricites australis	3	5	8	1	6	2	0
A. sp	1	2	3	6		1	0
Podocarpidites cf. ellipticus	2	8	10	8	9	8	0
P. marwickii	1	8	2	3	1	1	0
P. sp A		5		1	2	3	0
Microcachrydites antarcticus	14	23	28	25	14	16	0
Trichotomosulcites subgranulatus	5	4	10	17	7	11	0
Ephedra notensis				1			0
ANGIOSPERMS							0
Tricolpites lilliei	1			2		1	0
T. reticulatus	4	1	2	1			0
T. gillii	5	8	16	31	17	17	0
T. pachyexinus				2			0
T. species B	3	3		2	1		0
T. species E			1				0
T. species F	1	6	4	8		3	0
T. species J			1		1		0
T. species K			1	4			0
T. species L			1				0
T. species M				1	1		0
T. species N				1			0
Tricolporate sp C	2						0
Tetracolpites sp D				1			0
Nothofagus kaitangata	1	7	5	3	2	3	0
Caryophyllidites polyoratus		1					0
Polycolpites clavatus		1	1				0
Inaperture species A				1	1		0
L. variegatus	2	1		3			0
L. species B				1			0
Monosulcites granulatus	5	1	2	3	2	3	0
M. sub-granulatus	8	3	10	4	7	5	0
M. maxima	2						0
M. aff. minima		5	13	5	3	5	0
M. species B		2	1				0
M. species H	1	3					0
Proteacidites scaboratus			1	1	5	3	0
P. sp	22	18	13	3	39	39	0
P. sub-palisadus	1	1			15		0
P. species F						3	0
Beaupreadites sp.			1				0
T. fragilis				1			0
T. cf fragilis					3		0
	250	250	250	250	250	250	0

RAW COUNT DATA DH 343

SPECIES	UCP No.: 609s	608s	607s	606s	605s	604s	603s	602s	601s
	DEPTH: 283.90	272.65	196.40	183.70	153.30	145.81	123.44	114.90	102.84
SPORITES									
Peromonolites bowenii			2	1	2	3	16	3	1
Peromonolites sp					1				
Cyathidites minor	6	6	18	18	11	6	9	10	16
C. australis			1		1	1		1	
Baculatisporites comaumensis		1		4			4	2	1
Osmundacidites wellmanii				6	7	4	5	1	3
Polypodiidites cf. minimus				2	1		3	1	
P. species D			1	1					
P. species C		1	1		1		17	2	
Laevigatosporites ovatus	36	14	14	16	12	17	18	20	49
L. major	6					4	1	6	1
Clavifera triplex				3	1			2	
Gleicheniidites circinidites						2		4	1
Trilites species A				1	1				2
T. verrucatus	10	1	13	6	2	1	3	4	4
T. ohaiensis					2	3			
T. morleyi			2	1	1	1			
T. fragilis	1			1		5	2		
T. sinuatus									1
Ceratosporites equalis	2			1	2				
L. sp (fastigiatum volubile grp)	26	5	27	11	7	12	3		7
L. fastigoides	1	1	3	2		4	1		
L. species A	2							1	
L. sp							1		3
Stereisporites antiquasporites			4	4	14	8	4		2
Cingutriletes clavus	3		2			3			
S. strictus			3						
Krauselisporites majus									
GYMNOSPERMS									
Phyllocladidites mawsonii	27	12	10	68	79	31	36	50	37
Phyllocladus paleogenicus	17	4	3	11	6	5	3	5	5
Araucaricites australis	6	8			1	4	3	2	1
A. sp	4			3	3	8	6	1	6
Podocarpidites cf. ellipticus	7	9		2	10	18	3	8	9
P. marwickii	13	15		12	6	1	3	4	8
P. sp A	6	5		7	9		2	7	2
P. sp	7	7	4		8	5	1	7	4
Dacrydimites cf. prae-cupressinoides									
Microcachrydites antarcticus	20	11		14	14	17	15	25	11
Trichotomosulcites subgranulatus		3	2	3	7	9	2	9	2
T. species A			1						
ANGIOSPERMS									
Tricolpites lilliei		1		1	1	6			
T. reticulatus	1	3	1	1	2		1	3	1
T. gillii	15	91	22	21	17	10	16	14	19
T. pachyexinus						1		4	
T. verrucatus		1							
Tricolpate sp						2			
T. species B		4					3	4	
T. species D		1					1		
T. species E						1	1		
T. species F		4		1					
T. species J							1	1	
T. species K						1		1	
T. species L									
Tricolporate sp C						2		1	
Nothofagus kaitangata	2	14	2	8	2	13	7	16	11
Polycolpites clavatus		6				1	3	1	5
Inaperture species A						1			
L. variegatus		1	2		1	1	2	6	
L. species A		1							
M. sub-granulatus	6	10	9		5	6	9	6	5
M. maxima								2	
M. aff. minima	2	3		9	3	1	5	6	7
M. species B							1	2	
M. species C									
M. species H		2		1				1	1
M. species I							1		
Proteacidites scaboratus			1		1				
P. cf. amolosexinus									
P. sp	22	4	96	5	9	31	33	7	17
P. sub-palisadus			1						
P. species F				1					
P. species G				2		1			
P. sp		1	3						
Beaupreadites sp			1	1			4		5
Triorites minor							1		
T. fragilis									1
T. cf. fragilis									
T. subaveolatus									
T. species A	2								
T.species B									
	250	250	250	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA. DH 387

SPECIES	UCP No.: / DEPTH :	637s 117.01	636s 114.68	635s 112.68	634 104.29	633s 90.83	632 86.96	631s 74.41
SPORITES								
Peromonolites bowenii			4		3			1
Cyathidites minor		4	3	7	24		8	3
C. australis					2			
Baculatisporites comaumensis		12	4	11	9		2	3
Osmundacidites wellmanii				8	3	R		2
P. species B					2			
P. species C		1	6			E	1	10
Laevigatosporites ovatus		43	24	16	26		23	22
L. major		6	8		4	W	9	5
Clavifera triplex		1	1		1			
Gleicheniidites circinidites					1	O	1	1
Trilites species A			1		1		2	
T. verrucatus		1		1	3	R	1	1
T. ohaiensis							1	
T. morleyi					4	K		
T. fragilis			1					
Ceratosporites equalis			1	2	4	E	1	
L. sp (fastigiatum volubile grp)		2	3		12		1	4
L. fastigoides			1	1	1	D		
Stereisporites antiquasporites		2	2		16		9	
Cingutriletes clavus			1		5			
Kraeuselisporites majus					1			
GYMNOSPERMS								
Phyllocladidites mawsonii		32	26	12	3		26	22
Phyllolcadus paleogenicus		3	2	6	6		6	7
Araucaricites australis			6	14	7		9	20
A. sp			4	8				3
Podocarpidites cf. ellipticus		14	15	19			8	5
P. marwickii		8	16	7	5		14	12
P. sp A		1	4		1		7	11
P. sp		6	4	11	6		6	3
Microcachrydites antarcticus		13	22	11	2		13	16
Trichotomosulcites subgranulatus		6	6	1	4		12	8
ANGIOSPERMS								
Tricolpites lilliei		3	1	1	1		3	1
T. reticulatus		21	1		1		19	1
T. gillii		15	19	33	15		27	20
T. species B			6	2	1		2	
T. species E			1	1				1
T. species F		1	1		1		1	1
T. species J		1						1
T. species K			1					2
T. species M		1						
Tricolpites sp			1					3
Tricolporate species D		1						
Nothofagus kaitangata		13	30	44	4		21	25
Polycolpites clavatus		2	1					4
L. variegatus							3	
L. species D								1
Monosulcites granulatus							1	2
M. sub-granulatus		4	7	10	15		1	7
M. off. minima		16	5	7	13			7
M. species B			3					4
M. species C			1					
M. species H		1	1	10	1		2	1
M. species J					2			
M. species K				2	6			
Proteacidites scaboratus			1				2	2
P. retiformis							1	
P. sp		15	4	4	32		7	7
P. sub-palisadus					1			
P. species G		1		1				1
T. fragilis			1		1			
		250	250	250	250	0	250	250

Appendix 1 cont/

RAW COUNT DATA. DH 375
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UCP No.:	628s	627s	626	625s	624s	623s	622s	621s	620
SPECIES — DEPTH :	445.86	434.86	425.70	416.79	412.77	409.46	395.01	380.11	368.02
Peromonolites bowenii		6	3		2		4	2	3
Cyathidites minor	6	5	6	15	9	7	22	11	17
C. australis		2	2	1			1		
Baculatisporites comaumensis	5	8	3	3	1	1	20	1	3
Osmundacidites wellmanii	2	8	1	17			22	5	3
O. species A						1	6	5	4
Polypodiidites cf minimus					6			1	
P. species B				1		3		3	
P. species C	3	3	1	1	10	1			1
Laevigatosporites ovatus	34	56	30	34	24	27	30	31	23
L. major	2	13	7	6	7	1	22	4	8
Clavifera triplex			1		3	1			4
C. rudis								2	
Gleicheniidites circinidites				2		1		2	2
Trilites species A	2			6		1			2
T. species D						1			
T. verrucatus	3	2	2	2	2	2	1	1	9
T. cf. verrucatus	1								
T. ohaiensis		1	1						
T. morleyi		1							4
T. fragilis	1								
Ceratosporites equalis	1					1			1
L. sp (fastigiatum volubile grp)	2	6	2	7	4	1	7		11
L. species A					1				
L. sp.					2			1	1
Stereisporites antiquasporites				5	1		2		1
S. sp							1		
Foramisporis cf. asymmetricus				1					
Cingutriletes clavus								1	1
GYMNOSPERMS									
Phyllocladidites mawsonii	17	44	37	9	32	70	19	33	39
Phyllocladus paleogenicus	6	5	7	8	1	1	9	5	3
Araucaricites australis	9	2			2		2	1	1
A. sp	1					1	1	2	1
Podocarpidites cf. ellipticus	6	3	21	12	6	5	4	6	7
P. marwickii	12	4	37	9	8	14	3	3	7
P. major			1			1			1
P. sp A	12	7	8	7	4	7	4	3	2
P. sp	1	6	5	3	4	5	6		6
Microcachrydites antarcticus	21	7	44	9	13	15	13	18	21
Trichotomosulcites subgranulatus	5	12	10	7	7	7	3	4	1
ANGIOSPERMS									
Tricolpites lilliei	2		1	1	2	1	2	10	3
T. reticulatus	5	4	1			2	13	5	3
T. gillii	32	22	11	46	55	38	8	28	11
T. pachyexinus						2		2	
T. species B	3	2	1	8	1	4	3	4	1
T. species E		1	2	1		1			
T. species F				2		1	2	3	2
T. species G								1	1
T. species J				2		1			
T. species K		2	1			4			
T. species C							1		
T. species D	1								
Tetracolpites sp O	1								
Nothofagus kaitangata	30	4	2	2	15	1	2	18	15
Polycolpites clavatus	1	3		2	1	2		4	1
Inaperture species A					1				1
L. variegatus		1				1		1	1
Monosulcites granulatus						1			2
M. subgranulatus	2	2		8	9	7	3	5	1
M. maxima					4		2		3
M. aff. minima	4		1	7	2	3	1	9	5
M. species B						1	2		
M. species D					1				
M. species H		1		1		1	1	3	
M. species I		1						1	1
Proteacidites scaboratus	2								1
P. cf amolosexinus	1								1
P. sp	10	4	1	5	9	4	8	4	8
P. subpalisadus	2				1				
P. species F	1							1	
P. species G								1	
Beaupreadites sp	1							5	1
T. fragilis									1
T. cf. fragilis		2							
	250	250	250	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA DH335

SPECIES \ UCP No.	534s	533	532	531s	530	529s	528s	527	526	525	524s	523s	522s	521s	520s	519s
DEPTH :	374.35	364.74	351.18	344.71	334.40	324.34	314.29	305.52	299.00	291.85	284.10	272.72	263.92	250.70	242.36	230.60
SPORITES																
Peromonolites bowenii			1		1	1		3	2	6		1	2	1	4	1
Cyathidites minor	2	10	5			3	7	8		3	8	4	5	6	8	6
C. australis		1				1	1	2				1			1	4
Baculatisporites comaumensis	1				2		5	1	1							
B. species A																
B. sp	2		5	3		7	14	4				4		1	3	2
Osmundacidites wellmanii	6	3	3	5	4	10	5	5	7					2	3	2
O. species A				1												
Polypodiidites cf. minimus				1		1					2	1		1		
P. species A							1									
P. species C	1				1	1	1					3		1	1	
Laevigatosporites ovatus	22	28	44	25	37	30	69	18	37	9	29	26	30	19	25	16
L. major		2	5	6	10	8	20	11	4		7	13	16	5	9	2
Clavifera triplex								1		13		1				1
Gleicheniidites circinidites					1	1		3	3	5					2	1
Trilites species A	1			1				1	1						1	1
T. verrucatus		3				1	1	1	1	8	1	1	1	1	3	1
T. ohaiensis						1										
T. morleyi	2				1											
T. fragilis																1
T. sinuatus								1								
Ceratosporites equalis		1	1	1		2										1
L sp. (fastigiatum volubile grp)	2	15		6	2	4		3	5					2	2	9
L. fastigoides		1														
L. sp.							2			4						
Stereisporites antiquasporites			1	3		1		1							1	1
Cingutriletes regium																1
Leptolepidites verrucatus								1								
Camaronosporites cf. australiensus														1		
Foveotriletes sp.		1														
Cingutriletes clavus		1														
GYMNOSPERMS																
Phyllocladidites mawsonii	3	6	14	18	9	10	12	38	15	38	11	19	3	19	22	25
Phyllocladus paleogenicus	14	10	10	7	1	10	4	7	7	4	6	6	5	5	6	8
Araucaricites australis	5	7	7	6	4	13	6	4	8		4	10	6	10	3	5
A. sp	5	6	11 7		4	5	3	5	6		3	2	4	1		1
Podocarpidites cf. ellipticus	10	6	4	18	12	8	19	10	18	15	18	16	14	18	6	9
P. marwickii	10	5	12	12	7	3	14	4	6	8	7	6	11	3	3	3
P. major		1														
P. sp A	3	3	12	6	9	5	8			11						
Dacrydimites cf. prae-cupressinoides	2															
Microcachrydites antarcticus	17	17	25	33	23	8	29	14	24	56	22	23	16	33	27	30
Trichotomosulcites subgranulatus	5	6	5	15	16	6	5	9	9	7	12	7	3	8	11	9
T. species A	4		1	3	4	1			1	1						
Ephedra notensis	1															
ANGIOSPERMS																
Tricolpites lilliei	4	4		6	4				7		2		8	5		6
T. reticulatus	6			25	5	1	1	1	2		3	2	10	9	4	9
T. gillii	34	32	13	19	25	48	5	23	26	4	38	17	7	11	40	25
T. pachyexinus	1								1	2		3			2	1
T. species Y	1															
T. species Z		1														
T. species C											2					
T. species B				1	2	1		1				5	4	2	3	
T. species D				1												
T. species E				1	1			1	2	4	3	1			2	2
T. species F	3	1	3		1	5		23	9	2	16	10	5	5	7	6
T. species I	2															
T. species J			2						2		1	1		1		
T. species K	2	2	3	1	2	13		5	2		6	4		8	1	3
T. species L												1				
T. species M													1			
T. species N																1
T. species O			2			1										1
T. species P		1	1													
T. species Q													1			
Tri/poly colpate sp I		1														
Tricolporate sp B	4												1			

Appendix 1 cont/

Drillhole 335 cont/

T. species C	2															
T. species D				1												
T. species O	4							1								
Tetracolpites sp O												1	1		1	
Nothofagus kaitangata	31	23	2	5	24	5	1	2	13		13	33	51	48	16	22
Polycolpites clavatus	2	1	1		3	3						1	3			1
Polyorate species A	1											1				
Inaperture species A				1								1				
Liliacidites intermedius								1							1	
L. variegatus							1		1		2		2	2	3	2
L. species C			2													
Monosulcites granulatus	6	3	13	4	6	9	4	9	5		8	6	5	2	3	8
M. sub-granulatus	4	9	6	4	9	9	5	12	10	1	10	7	14		6	1
M. maxima					8	3	2						2			
M. aff. minima	4	10	2	4	6	2	4	7	4	3	10	6	8	6	8	3
M. species B											1					1
M. species C	3												1			2
M. species D					1							1		2		
M. species E														1		
M. species H						1						1				
Proteacidites scaboratus	1	1			2	1	1						2			1
P. retiformis					1			1							1	
P. sp	5	22		3	2	6		5	7	2	3	3	2	5	8	13
P. sub-palisadus	4		3	3						1	1		1	2		1
P. species F		2	1													
Gamberina rudata	1								1							
Beaupreadites sp											1		2		3	1
Triorites minor	1									1						
T. cf fragilis								1	1							
T. subaveolatus	2															
T. species A	1	4												1		
T. species C								1								
T. species Z	3			1					1							
Triorate/colpate sp H						1		1	1			1	3	3		
	250	250	220	250	250	250	250	250	250	208	250	250	250	250	250	250

Appendix 1 cont/

RAW COUNT DATA. DH 384

SPECIES	UCP No.: 648s DEPTH : 395.00	649s 414.20
SPORITES		
Peromonolites bowenii	1	3
Cyathidites minor	8	7
Baculatisporites comaumensis	5	1
Osmundacidites wellmanii		6
P. species A	1	
P. species C		3
Laevigatosporites ovatus	16	22
L. major		3
Clavifera triplex	1	1
Gleicheniidites circinidites		5
Trilites species A	1	3
T. verrucatus	2	9
T. fragilis	1	
Ceratosporites equalis	1	1
L. sp (fastigiatum volubile grp)	4	3
Stereisporites antiquasporites		1
GYMNOSPERMS		
Phyllocladidites mawsonii	23	35
Phyllocladus paleogenicus	3	4
Araucaricites australis	2	2
A. sp	3	
Podocarpidites cf. ellipticus	14	5
P. marwickii	9	5
P. sp A	7	6
P. sp		6
Microcachrydites antarcticus	17	11
Trichotomosulcites subgranulatus	4	3
ANGIOSPERMS		
Tricolpites lilliei	15	2
T. reticulatus	8	5
T. gillii	10	15
T. pachyexinus	2	
T. species A		
T. species B	6	
T. species F	4	
T. species J	1	
T. species M	1	
Tricolporate sp B		1
Nothofagus kaitangata	54	10
Polycolpites clavatus	4	
L. variegatus	1	
Monosulcites granulatus		
M. sub-granulatus	5	2
M. maxima	1	
M. aff. minima	2	7
M. species H	1	
M. species I	2	1
P. sp	9	8
Beaupreadites sp		1
T. cf. fragilis	1	
	250	197

Appendix 2

DRILLHOLE 387. POLLEN SUM 1 RELATIVE PERCENT DATA

UCP No.:	637s	636s	635s	634	632	631s
DEPTH :	117.01	114.69	112.68	104.29	86.96	74.41
Peromonolites bowenii	0	2	0	1	0	0
Cyathidites minor	2	1	3	10	3	1
Baculatisporites comaumensis	5	2	4	4	1	1
Osmundacidites wellmanii	0	0	3	1	0	1
P. species C	0	3	0	0	0	4
Laevigatosporites ovatus	18	10	7	11	10	9
L. major	2	3	0	2	4	2
Trilites verrucatus	0	0	0	1	0	0
T. morleyi	0	0	0	2	0	0
Ceratosporites equalis	0	0	1	2	0	0
L. sp (fastigiatum volubile grp)	1	1	0	5	0	2
Stereisporites antiquasporites	1	1	0	7	4	0
S. species C	0	0	0	2	0	0
	0	0	0	0	0	0
GYMNOSPERMS	0	0	0	0	0	0
Phyllocladidites mawsonii	13	11	5	1	11	9
Phyllocladus paleogenicus	1	1	2	3	2	3
Araucaricites australis	0	3	6	3	4	8
A. sp	0	2	3	0	0	1
Podocarpidites cf. ellipticus	6	6	8	0	3	2
P. marwickii	3	7	3	2	6	5
P. sp A	0	2	0	0	3	5
P. sp	2	2	4	3	2	1
Microcachrydites antarcticus	5	9	4	1	5	7
Trichotomosulcites subgranulatus	2	3	0	2	5	3
	0	0	0	0	0	0
	0	0	0	0	0	0
ANGIOSPERMS	0	0	0	0	0	0
Tricolpites lilliei	1	0	0	0	1	0
T. reticulatus	9	0	0	0	8	0
T. gillii	6	8	13	6	11	8
T. species B	0	3	1	0	1	0
Tricolpites sp	0	0	0	0	0	1
Nothofagus kaitangata	5	13	18	2	9	11
Polycolpites clavatus	1	0	0	0	0	2
L. variegatus	0	0	0	0	1	0
M. sub-granulatus	2	3	4	6	0	3
M. aff. minima	7	2	3	6	0	3
M. species B	0	1	0	0	0	2
M. species H	0	0	4	0	1	0
M. species K	0	0	1	3	0	0
P. sp	5	1	1	13	3	3

Appendix 2 cont /

DRILLHOLE 364. POLLEN SUM 1 RELATIVE PERCENT DATA

UCP No.	600s	599	598s	597	596s	595s	594s	593s	592	591s	590s	L12727/1	L12726/3	L12725/2
DEPTH :	434.00	426.80	411.30	381.50	375.40	358.00	353.80	343.55	332.30	323.85	313.60	305.74	296.53	287.89
SPORITES														
Peromonolites bowenii	0	2	0	0	0	1	0	0	1	2	0	0	2	0
Cyathidites minor	7	3	14	7	10	4	2	4	11	3	5	4	14	6
Baculatisporites comaumensis	0	1	1	6	2	2	0	0	1	0	0	1	1	2
Osmundacidites wellmanii	2	3	3	5	1	0	0	2	3	0	0	0	2	1
P. species C	0	0	1	0	0	0	0	0	0	0	0	0	6	0
P. species D	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Laevigatosporites ovatus	13	8	28	23	15	12	2	12	6	13	13	14	25	19
L. major	3	0	0	1	1	0	0	0	0	0	0	0	0	0
Clavifera triplex	0	1	0	0	0	2	2	0	0	0	1	0	1	0
Gleicheniidites circinidites	0	0	0	0	0	3	0	0	2	0	2	2	6	5
Trilites species A	0	1	0	0	0	0	0	0	2	0	0	0	0	0
T. verrucatus	1	0	4	1	0	7	0	0	2	0	1	0	2	2
T. morleyi	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Ceratosporites equalis	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Ceratosporites sp	0	0	0	0	0	0	0	0	0	0	0	0	2	1
L. sp (fastigiatum volubile grp)	1	3	0	0	0	1	1	1	2	3	0	5	9	2
L. fastigoides	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Stereisporites antiquasporites	0	1	0	0	0	0	0	0	1	0	0	0	5	0
Biretisporites sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GYMNOSPERMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii	5	21	5	7	7	22	62	9	33	6	47	16	0	9
Phyllocladus paleogenicus	1	3	3	0	2	2	2	2	2	1	2	2	0	3
Araucaricites australis	0	0	1	0	0	0	0	0	0	1	0	0	0	2
A. sp	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Podocarpidites cf. ellipticus	9	5	3	2	9	4	2	4	4	3	1	7	0	5
P. marwickii	3	3	1	2	0	0	6	1	2	5	2	10	0	3
P. sp 1	3	2	3	1	2	0	0	2	1	2	2	2	0	0
P. sp	0	1	1	2	1	2	3	3	3	2	0	5	0	0
Microcachrydites antarcticus	6	4	3	2	3	2	2	4	5	6	2	14	0	6
Trichotomosulcites subgranulatus	1	2	1	1	1	4	1	0	1	4	1	1	1	3
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANGIOSPERMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricolpites lilliei	1	0	2	1	1	1	0	0	0	2	1	3	0	1
T. reticulatus	11	0	1	2	1	1	0	0	1	2	0	0	0	1
T. gillii	11	18	6	16	21	13	2	24	4	18	4	4	3	9
T. species B	0	0	2	2	0	2	0	3	1	1	1	0	0	0
T. species F	1	0	2	2	2	1	0	0	0	0	0	0	0	0
Nothofagus kaitangata	8	7	3	8	4	2	9	12	4	8	5	0	0	4
Polycolpites clavatus	0	0	0	0	0	1	0	1	0	1	0	0	0	0
L. variegatus	1	0	1	0	0	1	0	0	0	0	0	0	0	0
M. sub-granulatus	1	1	4	3	2	4	0	2	2	3	2	0	3	5
M. aff. minima	6	4	1	1	5	2	0	2	1	5	1	0	5	3
M. species H	1	1	0	0	1	0	0	1	0	2	0	0	0	0
Proteacidites scaboratus	0	0	0	0	0	0	0	0	0	0	1	0	0	0
P. sp	0	3	5	1	4	5	2	1	2	2	2	6	3	4
P. species G	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Beaupreadites sp	0	0	0	0	2	1	0	6	0	0	0	0	0	0

Appendix 2 cont/

OH 335 POLLEN SUM I RELATIVE PERCENT

SPECIES	UEP No.:	534	533	532	531s	530	529s	528s	527	526	525	524s	523s	522s	521s	520s	519s
	DEPTH :	374.35	364.74	351.18	344.71	334.40	324.34	314.29	305.52	299.00	291.85	284.10	272.72	263.92	250.70	242.36	230.60
SPORITES																	
Peromonolites bowenii		0	0	0	0	0	0	0	1	1	3	0	0	1	0	2	0
Cyathidites minor		1	4	2	0	0	1	3	3	0	1	3	2	2	2	3	2
C. australis		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Baculatisporites comaumensis		0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0
B. sp		1	0	2	1	0	3	6	2	0	0	0	2	0	0	1	1
Osmundacidites wellmanii		3	1	1	2	2	4	2	2	3	0	0	0	0	1	1	1
P. species C		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Laevigatosporites ovatus		10	12	21	10	15	12	28	7	15	4	12	11	12	8	10	7
L. major		0	1	2	2	4	3	8	4	2	0	3	5	7	2	4	1
Clavifera triplex		0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
Gleicheniidites circinidites		0	0	0	0	0	0	0	1	1	2	0	0	0	0	1	0
T. verrucatus		0	1	0	0	0	0	0	0	0	4	0	0	0	0	1	0
L. sp (fastigiatum volubile grp)		1	6	0	2	1	2	0	1	2	0	0	0	0	1	1	4
L. sp.		0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
Stereisporites antiquasporites		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GYMNOSPERMS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii		1	3	7	7	4	4	5	16	6	18	5	8	1	8	9	10
Phyllocladus paleogenicus		6	4	5	3	0	4	2	3	3	2	2	2	2	2	2	3
Araucaricites australis		2	3	3	2	2	5	2	2	3	0	2	4	2	4	1	2
A. sp		2	3	5	0	2	2	1	2	2	0	1	1	2	0	0	0
Podocarpidites cf. ellipticus		4	3	2	7	5	3	8	4	7	7	7	7	6	7	2	4
P. marwickii		4	2	6	5	3	1	6	2	2	4	3	2	5	1	1	1
P. sp A		1	1	6	2	4	2	3	0	0	5	0	0	0	0	0	0
Microcachrydites antarcticus		7	7	12	14	9	3	12	6	10	27	9	10	7	14	11	12
Tricholomosulcites subgranulatus		2	3	2	6	7	2	2	4	4	3	5	3	1	3	4	4
T. species A		2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANGIOSPERMS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricolpites lilliei		2	7	0	2	2	0	0	0	3	0	1	0	3	2	0	2
T. reticulatus		3	0	0	10	2	0	0	0	1	0	1	1	4	4	2	4
T. gillii		15	13	6	8	10	20	2	9	11	2	16	7	3	5	16	10
T. pachyexinus		0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
T. species B		0	0	0	0	1	0	0	0	0	0	0	2	2	1	1	0
T. species E		0	0	0	0	0	0	0	0	1	2	1	0	0	0	1	1
T. species F		1	0	1	0	0	2	0	9	4	1	7	4	2	2	3	2
T. species K		1	1	1	0	1	5	0	2	1	0	2	2	0	3	0	1
T. species O		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nothofagus kaitangata		14	10	1	2	10	2	0	1	5	0	5	14	21	20	7	9
Polycolpites clavatus		1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0
L. variegatus		0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
Monosulcites granulatus		3	1	6	2	2	4	2	4	2	0	3	2	2	1	1	3
M. sub-granulatus		2	4	3	2	4	4	2	5	4	0	4	3	6	0	2	0
M. maxima		0	0	0	0	3	1	1	0	0	0	0	0	1	0	0	0
M. minima		0	0	0	0	0	0	2	3	2	1	4	0	3	2	3	1
M. aff.minima		2	4	1	2	2	1	0	0	0	0	0	2	0	0	0	0
M. species C		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
P. retiformis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. sp		2	8	0	1	0	1	0	2	3	1	1	1	1	2	3	5
P. sub-palisadus		2	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0
T. species A		0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. species B		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. species C		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. species Z		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2 cont/

DRILLHOLE 375. POLLEN SUM 1 RELATIVE PERCENT DATA

UCP No.:	628s	627s	626	625s	624s	623s	622s	621s	620
DEPTH :	445.86	434.86	425.78	416.79	412.77	409.46	395.01	380.11	368.02
Peromonolites bowenii	0	2	1	0	1	0	2	1	1
Cyathidites minor	3	2	2	6	4	3	9	5	7
Baculatisporites comaumensis	2	3	1	1	0	0	8	0	1
Osmundacidites wellmanii	1	3	0	7	0	0	9	2	1
O. species A	0	0	0	0	0	0	2	2	2
Polypodiidites cf. minimus	0	0	0	0	2	0	0	0	0
P. species B	0	0	0	0	0	1	0	1	0
P. species C	1	1	0	0	4	0	0	0	0
Laevigatosporites ovatus	14	23	12	14	10	11	12	13	10
L. major	1	5	3	2	3	0	9	2	3
Clavifera triplex	0	0	0	0	1	0	0	0	2
Trilites species A	1	0	0	2	0	0	0	0	1
T. verrucatus	1	1	1	1	1	1	0	0	4
T. morleyi	0	0	0	0	0	0	0	0	2
L. sp (fastigiatum volubile grp)	1	2	1	3	2	0	3	0	5
Stereisporites antiquasporites	0	0	0	2	0	0	1	0	0
	0	0	0	0	0	0	0	0	0
GYMNOSPERMS	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii	7	18	15	4	13	29	8	14	17
Phyllocladus paleogenicus	3	2	3	3	0	0	4	2	1
Araucaricites australis	4	1	0	0	1	0	1	0	0
Podocarpidites cf. ellipticus	3	1	9	5	2	2	2	3	3
P. marwickii	5	2	15	4	3	6	1	1	3
P. sp A	5	3	3	3	2	3	2	1	1
P. sp	0	2	2	1	2	2	2	0	3
Microcachrydites antarcticus	9	3	18	4	5	6	5	8	9
Trichotomosulcites subgranulatus	2	5	4	3	3	3	1	2	0
	0	0	0	0	0	0	0	0	0
ANGIOSPERMS	0	0	0	0	0	0	0	0	0
Tricolpites lilliei	1	0	0	0	1	0	1	4	1
T. reticulatus	2	2	0	0	0	1	5	2	1
T. gillii	13	9	5	19	23	16	3	12	5
T. species B	1	1	0	3	0	2	1	2	0
T. species F	0	0	0	1	0	0	1	1	1
T. species K	0	1	0	0	0	2	0	0	0
Nothofagus kaitangata	13	2	1	1	6	0	1	8	6
Polycolpites clavatus	0	1	0	1	0	1	0	2	0
M.subgranulatus	1	1	0	3	4	3	1	2	0
M. maxima	0	0	0	0	2	0	1	0	1
M. aff. minima	2	0	0	3	1	1	0	4	2
M. species H	0	0	0	0	0	0	0	1	0
P. scaboratus	1	0	0	0	0	0	0	0	0
P. sp	3	2	0	2	4	2	3	1	3
T.species B	0	0	0	0	0	0	0	2	0

Appendix 2 cont/

DRILLHOLE 382. POLLEN SUM I RELATIVE PERCENT DATA

UCP No	557s	558	559s	560s	561	562	563s	564	565s	566	567	568s	569	570	571s	572s	573s
DEPTH	243.92	254.36	262.90	273.20	278.98	303.94	314.40	324.40	333.41	344.26	359.75	369.18	378.40	389.64	395.70	402.27	404.30
SPORITES																	
Peromonolites bowenii	0	0	0	0	0	1	0	0	0	1	2	0	1	0	0	0	0
Cyathidites minor	0	5	7	5	11	5	8	6	4	5	2	3	3	0	1	2	4
C. australis	4	2	0	1	2	2	2	0	1	0	1	0	0	0	0	0	0
Baculatisporites comaumensis	0	3	3	0	1	0	0	0	0	0	0	0	0	0	2	2	0
B. sp	3	0	0	0	0	0	1	2	1	2	0	0	5	0	0	0	0
Osmundacidites wellmanii	4	2	4	2	2	0	1	2	2	2	0	0	9	2	3	0	1
O. species A	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. species B	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P. species C	8	0	0	0	0	0	1	1	1	5	0	1	2	0	0	0	0
Laevigatosporites ovatus	4	7	14	11	16	6	9	16	8	16	10	18	21	11	14	21	10
L. major	0	3	0	2	3	1	3	4	1	4	2	2	5	1	5	1	2
Clavifera triplex	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gleicheniidites circinidites	0	0	2	2	0	2	3	0	0	0	2	0	1	0	0	0	0
Trilites species A	0	0	0	0	1	0	1	0	0	0	0	0	0	2	0	0	1
T. species D	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T. verrucatus	0	2	2	1	1	2	1	2	2	1	2	0	1	0	0	0	0
T. fragilis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratosporites equalis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
L. sp (fastigiatum volubile grp)	0	2	2	3	3	2	2	0	5	2	4	7	8	3	3	3	3
Stereisporites antiquasporites	0	0	0	1	0	2	1	0	0	2	2	1	0	2	0	0	0
Cingutriletes clavus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Kraeuselisporites majus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GYMNOSPERMS	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii	1	12	4	8	8	21	16	5	9	10	12	7	1	8	2	2	1
Phyllocladus paleogenicus	0	1	1	1	0	4	6	1	4	2	5	12	0	3	1	2	5
Araucaricites australis	2	3	2	1	2	2	1	3	1	0	2	2	1	1	3	1	8
A. sp	8	0	1	1	1	0	1	1	1	0	3	2	1	2	2	1	4
Podocarpidites cf. ellipticus	5	5	8	4	5	5	1	4	2	4	5	3	0	5	5	5	8
P. marwickii	0	2	2	3	2	4	3	4	2	1	8	1	0	2	3	0	2
P. sp I	3	3	2	3	3	2	2	3	1	0	2	3	0	4	1	0	2
P. sp	12	3	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0
Microcachrydites antarcticus	1	13	13	8	10	9	8	7	3	2	7	3	1	15	7	3	3
Trichotomosulcites subgranulatus	0	2	2	2	0	1	4	2	2	1	3	4	0	6	4	4	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANGIOSPERMS	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricolpites lilliei	2	5	0	2	4	0	0	2	1	0	0	0	0	0	0	0	3
T. reticulatus	4	2	1	1	4	1	0	0	1	2	0	0	0	9	19	0	0
T. gillii	3	6	7	10	6	6	8	17	9	13	10	7	9	8	6	17	14
T. species B	0	0	0	2	0	0	1	2	3	2	0	1	0	2	2	2	1
T. species F	0	0	1	1	0	0	0	1	2	4	1	1	0	1	0	2	1
T. species K	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	3
T. species L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. species C	18	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Nothofagus kaitangata	0	8	2	15	1	2	2	6	2	3	2	2	2	0	6	12	9
Polycolpites clavatus	0	0	0	1	0	0	0	0	18	1	0	0	2	0	0	1	1
L. variegatus	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1
Monosulcites granulatus	2	1	0	0	0	0	0	1	0	2	1	0	1	1	0	3	2
M. sub-granulatus	0	0	4	0	0	1	1	2	3	5	2	1	3	2	2	4	3
M. maxima	0	0	0	0	0	0	0	1	0	1	0	0	2	0	1	0	0
M. minima	0	0	0	0	0	0	0	0	0	0	0	0	4	4	2	0	0
M. aff. minima	0	0	0	0	2	2	0	2	0	0	0	4	0	0	0	0	0
M. species A	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
M. species C	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
M. species I	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Proteacidites scaboratus	0	0	0	0	0	1	2	0	0	1	2	0	0	0	0	0	1
P. sp	0	3	5	4	4	10	7	0	7	5	3	9	9	2	3	7	5
P. species G	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Appendix 2 cont/

DRILLHOL 347. POLLEN SUM I RELATIVE PERCENT DATA

SPECIES	UCP No.: 574s DEPTH : 145.60	575s 150.00	576 160.65	577s 174.85	578 205.15	579 208.20
SPORITES						
Peromonolites bowenii	0	0	1	0	0	0
Cyathidites minor	9	5	3	2	4	4
C. australis	2	0	0	0	0	0
Baculatisporites comaumensis	5	5	0	0	0	0
B. sp	5	1	0	0	0	0
Osmundacidites wellmanii	6	4	0	0	0	1
P. species C	0	1	0	0	2	0
Laevigatosporites ovatus	13	12	8	10	11	7
L. major	10	1	0	4	2	1
Gleicheniidites circinidites	0	2	0	0	0	0
Trilites species A	0	1	1	0	0	0
T. verrucatus	0	2	0	0	0	1
L. sp (fastigiatum volubile grp)	5	2	2	1	6	5
Ster3isporites antiquasporites	1	5	3	0	2	6
S. species C	0	2	0	0	0	0
GYMNOSPERMS						
Phyllocladidites mawsonii	7	5	25	22	8	13
Phyllocldus paleogenicus	5	5	5	5	10	11
Araucaricites australis	1	2	3	0	2	1
A. sp	0	1	1	3	0	0
Podocarpidites cf. ellipticus	1	3	4	3	4	3
P. marwickii	0	3	1	1	0	0
P. sp A	0	2	0	0	1	1
Microcachrydites antarcticus	6	9	12	11	6	7
Trichotomosulcites subgranulatus	2	2	4	7	3	4
ANGIOSPERMS						
T. reticulatus	2	0	1	0	0	0
T. gillii	2	3	7	13	7	7
T. species B	1	1	0	1	0	0
T. species F	0	2	2	3	0	1
Nothofagus kaitangata	0	3	2	1	1	1
L. variegatus	1	0	0	1	0	0
Monosulcites granulatus	2	0	1	1	1	1
M. sub-granulatus	3	1	4	2	3	2
M. aff. minima	0	2	5	2	1	2
M. species H	0	1	0	0	0	0
Proteacidites scaboratus	0	0	0	0	2	1
P. sp	9	7	5	1	15	15
P. sub-palisadus	0	0	0	0	6	0
P. species F	0	0	0	0	0	1
T. cf. fragilis	0	0	0	0	1	0

Appendix 2 cont/

DRILLHOLE 343. POLLEN SUM 1 RELATIVE PERCENT DATA

UCP No.:	609s	608s	607s	606s	605s	604s	603s	602s	601s
SPECIES — DEPTH :	283.90	272.65	196.40	183.70	153.30	145.81	123.44	114.90	102.84
SPORITES									
Peromonolites bowenii	0	0	1	0	1	1	7	1	0
Cyathidites minor	2	2	7	7	5	3	4	4	7
Baculatisporites comaumensis	0	0	0	2	0	0	2	1	0
Osmundacidites wellmanii	0	0	0	2	3	2	2	0	1
Polypodiidites cf. minimus	0	0	0	1	0	0	1	0	0
P. species C	0	0	0	0	0	0	7	1	0
Laevigatosporites ovatus	15	6	6	7	5	7	7	8	20
L. major	2	0	0	0	0	2	0	3	0
Clavifera triplex	0	0	0	1	0	0	0	1	0
Gleicheniidites circinidites	0	0	0	0	0	1	0	2	0
Trilites. verrucatus	4	0	5	2	1	0	1	2	2
T. ohaiensis	0	0	0	0	1	1	0	0	0
T. fragilis	0	0	0	0	0	2	1	0	0
L. sp (fastigiatum volubile grp)	11	2	11	5	3	5	1	0	3
L. fastigoides	0	0	1	1	0	2	0	0	0
L. sp.	0	0	0	0	0	0	0	0	1
Stereisporites antiquasporites	0	0	2	2	6	3	2	0	1
Cingutriletes clavus	1	0	1	0	0	1	0	0	0
S. strictus	0	0	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
GYMNOSPERMS	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii	11	5	4	28	33	13	15	21	15
Phyllocladus paleogenicus	7	2	1	5	2	2	1	2	2
Araucaricites australis	2	3	0	0	0	2	1	1	0
A. sp	2	0	0	1	1	3	2	0	2
Podocarpidites cf. ellipticus	3	4	0	1	4	8	1	3	4
P. marwickii	5	6	0	5	2	0	1	2	3
P. sp A	2	2	0	3	4	0	1	3	1
P. sp	3	3	2	0	3	2	0	3	2
Microcachrydites antarcticus	8	4	0	6	6	7	6	10	5
Trichotomosulcites subgranulatus	0	1	1	1	3	4	1	4	1
	0	0	0	0	0	0	0	0	0
ANGIOSPERMS	0	0	0	0	0	0	0	0	0
Tricolpites lilliei	0	0	0	0	0	3	0	0	0
T. reticulatus	0	1	0	0	1	0	0	1	0
T. gillii	6	37	9	9	7	4	7	6	8
T. pachyexinus	0	0	0	0	0	0	0	2	0
T. species B	0	2	0	0	0	0	1	2	0
T. species F	0	2	0	0	0	0	0	0	0
Nothofagus kaitangata	1	6	1	3	1	5	3	7	5
Polycolpites clavatus	0	2	0	0	0	0	1	0	2
L. variegatus	0	0	1	0	0	0	1	3	0
M. sub-granulatus	2	4	4	0	2	3	4	3	2
M. aff minima	1	1	0	4	1	0	2	3	3
P. sp	9	2	40	2	4	13	14	3	7
P. sp	0	0	1	0	0	0	0	0	0
Beaupreadites sp	0	0	0	0	0	0	2	0	2
	20	59	56	21	16	31	36	30	30

Appendix 2 cont/

DRILLHOLE 336 (B).POLLEN SUM 1 REL.PERCENT

UCP No.:	555	554	553	552s	551	550s	549s	548	547	546s	545s	544s	543s	542s
SPECIES — DEPTH :	388.45	379.00	367.30	353.30	337.20	323.76	309.69	288.80	277.96	273.70	258.69	249.74	230.11	219.80
SPORITES														
Peromonolites bowenii	0	1	2	0	2	1	2	0	3	0	1	0	0	0
Cyathidites minor	2	0	0	1	0	5	5	3	3	4	3	2	0	3
Baculatisporites comaumensis	3	2	1	1	0	0	2	0	3	1	0	0	0	0
B. sp	3	2	2	1	0	0	1	0	4	3	2	3	0	0
Osmundacidites wellmanii	2	1	2	7	2	0	6	1	10	2	0	1	1	7
O. sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. species A	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P. species C	1	0	0	0	0	30	2	1	1	2	1	0	0	0
Laevigatosporites ovatus	9	6	14	12	9	13	13	10	11	25	9	13	13	12
L. major	0	0	4	2	2	0	2	2	1	5	1	4	3	2
Clavifera triplex	0	0	0	0	2	0	0	0	2	0	0	0	1	0
Gleicheniidites circinidites	0	0	0	0	1	0	0	0	0	0	2	0	0	1
Trilites species A	0	0	0	0	0	0	0	0	2	0	0	0	0	0
T. species C	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. verrucatus	0	0	0	1	2	1	2	2	1	1	1	10	0	0
T. morleyi	0	0	0	0	0	0	2	0	0	0	0	0	0	0
T. fragilis	0	0	0	0	0	0	0	0	0	0	0	1	0	0
L. sp (fastigiatum volubile grp)	7	7	2	2	0	1	12	1	0	1	0	0	1	4
L. species A	2	0	0	0	0	0	0	0	0	0	0	0	0	0
L. sp.	4	2	1	0	0	0	2	0	0	0	0	0	0	0
Stereisporites antiquasporites	3	1	1	1	1	2	11	0	1	0	2	0	0	1
Cingutriletes clavus	2	2	0	0	0	0	0	0	0	0	0	0	0	0
L. major	0	0	0	0	0	2	0	0	0	0	1	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GYMNOSPERMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllocladidites mawsonii	10	19	2	5	30	4	1	4	1	3	25	5	9	7
Phyllocladus paleogenicus	3	6	3	2	4	2	1	1	0	1	2	0	2	3
Araucaricites australis	0	1	2	2	0	1	0	3	2	0	0	5	0	1
A. sp	0	1	4	4	1	6	3	7	3	3	3	7	2	2
Podocarpidites cf. ellipticus	3	5	4	4	3	2	0	3	2	3	2	1	2	2
P. marwickii	1	3	2	1	4	0	0	2	2	2	0	0	0	2
P. major	0	0	2	0	0	0	0	0	0	0	0	0	0	0
P. sp	3	7	3	6	11	0	1	2	2	3	2	2	2	7
D. cf prae-cupressinoides	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcachrydites antarcticus	1	0	5	8	5	3	2	14	10	8	7	11	6	14
Tricholomosulcites subgranulatus	8	7	12	5	5	1	1	3	2	2	3	5	1	2
T. species A	0	0	0	2	0	0	0	1	0	0	0	2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANGIOSPERMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricolpites lilliei	0	1	2	3	2	0	0	0	0	2	0	2	0	0
T. reticulatus	1	0	4	6	0	0	1	2	4	6	3	2	0	0
T. gillii	8	7	3	3	6	4	2	7	9	8	5	3	11	3
T. species B	0	1	2	0	0	0	0	2	2	1	3	0	2	0
T. species E	0	0	1	3	0	0	0	0	2	0	0	0	0	0
T. species F	0	0	1	0	1	0	1	1	6	4	1	1	3	1
T. sp sub F	0	0	2	0	0	0	0	2	0	0	0	0	0	0
Tri/poly colpate sp I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricolporate sp C	0	0	0	0	0	0	0	2	0	0	0	0	0	0
T. species D	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elytranthe striatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E. cf striatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Cupaniedites orthoteichus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetracolporites species A	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Nothofagus kaitangata	1	1	8	1	1	2	1	9	3	4	7	9	23	4
Polycolpites clavatus	0	0	0	1	0	3	0	0	1	3	1	0	1	0
Inaperture sp A	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Liliacidites intermedius	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L. variegatus	1	0	2	2	0	0	1	2	0	0	0	0	0	1
L. sp C	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Monosulcities granulatus	1	0	3	2	1	4	5	5	2	1	2	2	0	2
M. sub-granulatus	0	0	0	0	0	0	0	1	0	0	2	0	4	0
M. aff. minima	0	0	0	0	0	5	3	1	3	0	1	1	0	0
M. sp A	1	0	0	0	0	0	0	0	0	0	0	0	0	0
M. sp B	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Proteacidites scabratus	0	0	0	0	0	0	0	0	0	0	1	0	0	0
P. cf. retiformis	8	9	2	1	0	2	8	4	0	3	0	2	6	14
P. sub-palisadus	0	0	1	1	0	0	1	0	0	0	1	0	1	0
P. sp	6	4	0	0	0	1	4	0	0	0	0	0	0	0
Triorites minor	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Beaupreadites sp	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Triporate/colpate sp H	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Appendix 3

DRILLHOLE 336. POLLEN SUM 2 RELATIVE PERCENTAGE DATA

SPECIES	UCP No	555	554	553	552s	551	550s	549s	548	547	546s	545s	544s	543s	542s
	Depth	388.45	379.00	367.30	353.30	337.20	323.76	309.69	288.80	277.96	273.70	258.69	249.74	230.11	219.80
Phyllocladidites mawsonii		44	46	6	20	52	31	14	12	6	12	54	18	20	18
Phyllocladus paleogenicus		13	15	11	8	7	19	21	2	0	4	5	0	6	8
Podocarpidites cf. ellipticus		12	11	13	14	5	13	0	8	9	12	5	3	4	4
P. marwickii		4	7	7	5	6	0	0	5	9	8	0	0	0	6
P. major		2	1	7	0	0	0	0	0	2	0	1	0	0	0
P. sp		13	17	11	21	19	3	14	7	11	12	5	6	5	17
Microcachrydites antarcticus		6	1	18	30	9	22	36	40	49	37	16	40	14	37
Nothofagus kaitangata		6	3	28	3	2	13	14	25	15	17	14	32	52	9

DRILLHOLE 343. POLLEN SUM 2 RELATIVE PERCENT DATA

	UCP No	609s	608s	607s	606s	605s	604s	603s	602s	601s
	Depth	283.90	272.65	196.40	183.70	153.30	145.81	123.44	114.90	102.84
Phyllocladidites mawsonii		27	16	53	56	59	34	51	41	43
Phyllocladus paleogenicus		17	5	16	9	4	6	4	4	6
Podocarpidites cf. ellipticus		7	12	0	2	7	20	4	7	10
P. marwickii		13	19	0	10	4	1	4	3	9
P. sp 1		6	6	0	6	7	0	3	6	2
P. sp		7	9	21	0	6	6	1	6	5
Microcachrydites antarcticus		20	14	0	11	10	19	21	20	13
Nothofagus kaitangata		2	18	11	7	1	14	10	13	13

DRILLHOLE 347. POLLEN SUM 2 RELATIVE PERCENTAGE DATA

SPECIES	UCP No	574s	575s	576	577s	578	579
	Depth	145.60	150.00	160.65	174.85	205.15	208.20
Phyllocladidites mawsonii		37	16	50	50	27	36
Phyllocladus paleogenicus		24	15	11	12	34	30
Podocarpidites cf. ellipticus		4	11	9	8	12	9
P. marwickii		2	11	2	3	1	1
P. sp		0	7	0	1	3	3
Microcachrydites antarcticus		30	31	24	24	19	17
Nothofagus kaitangata		2	9	4	3	3	3

DRILLHOLE 364. POLLEN SUM 2 RELATIVE PERCENTAGE DATA

	UCP No	600s	599	598s	597	596s	595s	594s	593s	592	591s	590s	L12727/1	L12726/3	L12725/2
	Depth	434.00	426.80	411.30	381.50	375.40	358.00	353.80	343.55	332.30	323.05	313.60	305.74	296.53	287.89
Phyllocladidites mawsonii		14	45	25	26	23	65	72	24	63	18	77	27	0	30
Phyllocladus paleogenicus		2	7	13	0	7	6	2	6	3	3	4	4	0	11
Podocarpidites cf. ellipticus		25	10	15	10	31	11	2	10	7	8	2	13	0	15
P. marwickii		8	7	4	8	1	0	8	2	5	16	3	17	0	10
P. sp 1		8	5	11	5	9	0	0	7	2	5	3	4	0	1
P. sp		1	2	6	10	3	6	3	8	5	7	0	9	0	0
Microcachrydites antarcticus		17	8	15	10	11	5	2	10	9	18	3	24	0	19
Nothofagus kaitangata		24	15	11	32	14	6	11	33	7	25	7	1	0	14

DRILLHOLE 375. POLLEN SUM 2 RELATIVE PERCENT DATA

SPECIES	UCP No	628s	627s	626	625s	624s	623s	622s	621s	620
	Depth	445.86	434.86	425.78	416.79	412.77	409.46	395.01	300.11	368.02
Phyllocladidites mawsonii		23	58	23	16	47	60	33	49	46
Phyllocladus paleogenicus		8	7	4	14	1	1	16	7	4
Podocarpidites cf. ellipticus		8	4	13	21	9	4	7	9	8
P. marwickii		16	5	23	16	12	12	5	4	8
P. sp 1		16	9	5	12	6	6	7	4	2
P. sp		1	8	3	5	6	4	10	0	7
Microcachrydites antarcticus		28	9	28	16	19	13	22	26	25
Nothofagus kaitangata		29	5	1	3	18	1	3	21	15

Appendix 3 cont/

DRILLHOLE 382. POLLEN SUM 2 RELATIVE PERCENT DATA

UCP No	557s	558	559s	560s	561	562	563s	564	565s	566	567	568s	569	570	571s	572s	573s
Depth	243.92	254.36	262.90	273.20	278.98	303.94	314.40	324.40	333.41	344.26	359.75	369.18	378.40	389.64	395.70	402.27	404.30
Phyllocladidites mawsonii	9	26	12	19	28	44	42	17	38	45	28	23	25	22	10	10	3
Phyllocaldus paleogenicus	2	3	4	3	1	9	15	4	16	9	12	37	8	9	5	8	16
Podocarpidites cf. ellipticus	16	10	23	10	18	11	2	12	9	17	11	10	8	13	20	18	26
P. marwickii	9	5	7	7	6	9	8	12	7	6	19	3	0	5	12	2	6
P. sp 1	1	6	7	7	10	4	5	10	4	0	5	10	0	11	3	2	7
P. sp	5	6	2	0	0	0	3	4	4	2	2	1	0	0	0	0	0
Microcachrydites antarcticus	22	27	39	19	33	19	20	23	14	8	18	9	25	39	27	11	10
Nothofagus kaitangata	35	17	5	36	4	4	4	19	9	13	4	8	33	1	23	49	32

DRILLHOLE 335. POLLEN SUM 2 RELATIVE PERCENT DATA

SPECIES	UCP No.:	534s	533	532	531s	530	529s	528s	527	526	525	524s	523s	522s	521s	520s	519s
	DEPTH :	374.35	364.74	351.18	344.71	334.40	324.34	314.29	305.52	299.00	291.85	284.10	272.72	263.92	250.70	242.36	230.60
Phyllocladidites mawsonii		3	8	18	18	11	20	14	51	18	29	14	18	3	15	28	26
P. paleogenicus		16	14	13	7	1	20	5	9	8	3	8	6	5	4	8	8
Podocarpidites ellipticus		11	8	5	18	14	16	22	13	22	11	23	16	14	14	8	9
P. marwickii		11	7	15	12	8	6	16	5	7	6	9	6	11	2	4	3
P. major		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. sp		3	4	16	6	11	10	9	0	0	8	0	0	0	0	0	0
Microchacrydites antarcticus		19	24	32	33	27	16	33	19	29	42	29	22	16	26	34	31
Nothofagus kaitangata		35	32	3	5	28	10	1	3	16	0	17	32	51	38	20	23

DRILLHOLE 387. POLLEN SUM 2 RELATIVE PERCENTAGE DATA

SPECIES	UCP No	637s	636s	635s	634	632	631s
	Depth	117.01	114.68	112.68	104.29	86.96	74.41
Phyllocladidites mawsonii		36	22	11	11	26	22
Phyllocladus paleogenicus		3	2	5	22	6	7
Podocarpidites cf. ellipticus		16	13	17	0	8	5
P. marwickii		9	13	6	19	14	12
P. sp A		1	3	0	4	7	11
P. sp		7	3	10	22	6	3
Microcachrydites antarcticus		14	18	10	7	13	16
Nothofagus kaitangata		14	25	40	15	21	25

Appendix 4

DH335. POLLEN SUM 3 REL.PERCENT

SPECIES																
UCP No.:	534	533	532	531s	530	529s	528s	527	526	525	524s	523s	522s	521s	520s	519s
DEPTH :	374.35	364.74	351.18	344.71	334.40	324.34	314.29	305.52	299.00	291.85	284.10	272.72	263.92	250.70	242.36	230.60
Phyllocladidites mawsonii	5	13	18	19	15	23	14	52	21	29	17	27	6	24	34	33
Phyllocladus paleogenicus	25	21	13	7	2	23	5	10	10	3	9	9	10	6	9	11
Podocarpidites cf. ellipticus	18	13	5	19	20	18	22	14	26	11	28	23	29	23	9	12
P. marwickii	18	11	16	13	11	7	16	5	9	6	11	9	22	4	5	4
P. sp	5	6	16	6	15	11	9	0	0	8	0	0	0	0	0	0
Microcachrydites antarcticus	30	36	32	35	38	18	34	19	34	42	34	33	33	42	42	40

DRILLHOLE 336. POLLEN SUM 3 REL.PERCENT

SPECIES														
UCP No.:	555	554	553	552s	551	550s	549s	548	547	546s	545s	544s	543s	542s
DEPTH :	388.45	379.00	367.30	353.30	337.20	323.76	309.69	288.80	277.96	273.70	258.69	249.74	230.11	219.80
Phyllocladidites mawsonii	47	47	8	20	53	36	17	16	8	14	63	27	42	20
Phyllocladus paleogenicus	14	15	15	8	7	21	25	3	0	5	6	0	12	9
Podocarpidites cf. ellipticus	12	11	17	14	5	14	0	11	10	14	5	5	8	5
P. marwickii	4	7	10	5	6	0	0	6	10	9	0	0	0	7
P. major	2	1	10	0	0	0	0	0	3	0	1	0	0	0
P. sp	14	17	15	22	19	4	17	10	13	14	5	9	10	19
Microcachrydites antarcticus	6	1	25	31	9	25	42	53	58	44	19	59	29	41

DH343. POLLEN SUM 3 REL.PERCENT

UCP No.:	609s	608s	607s	606s	605s	604s	603s	602s	601s
DEPTH :	283.90	272.65	196.40	183.70	153.30	145.81	123.44	114.90	102.84
Phyllocladidites mawsonii	28	19	59	60	60	40	57	47	49
Phyllocladus paleogenicus	18	6	18	10	5	6	5	5	7
Podocarpidites cf. ellipticus	7	14	0	2	8	23	5	8	12
P. marwickii	13	24	0	11	5	1	5	4	11
P. sp A	6	8	0	6	7	0	3	7	3
P. sp	7	11	24	0	6	6	2	7	5
Microcachrydites antarcticus	21	17	0	12	11	22	24	24	14

DH347. POLLEN SUM 3 REL.PERCENT

SPECIES						
UCP No.:	574s	575s	576	577s	578	579
DEPTH :	145.60	150.00	160.65	174.85	205.15	208.20
Phyllocladidites mawsonii	38	18	53	51	28	37
Phyllocladus paleogenicus	24	16	12	12	35	31
Podocarpidites cf. ellipticus	4	12	9	8	13	9
P. marwickii	2	12	2	3	1	1
P. sp	0	7	0	1	3	3
Microcachrydites antarcticus	31	34	25	25	20	18

DH364 POLLEN SUM 3 REL.PERCENT

UCP No.	600s	599	598s	597	596s	595s	594s	593s	592	591s	590s	L12727/1	L12726/3	L12725/2
DEPTH :	434.00	426.80	411.30	381.50	375.40	358.00	353.80	343.55	332.30	323.85	313.60	305.74	296.53	287.89
Phyllocladidites mawsonii	19	54	28	38	27	69	81	36	67	25	83	28	0	35
Phyllocladus paleogenicus	3	9	15	0	8	7	2	8	3	4	4	4	0	13
Podocarpidites cf. ellipticus	33	12	17	14	37	12	3	15	7	11	2	13	0	17
P. marwickii	11	9	4	12	2	0	8	3	5	21	4	17	0	11
P. sp A	11	5	13	7	10	0	0	10	2	7	4	4	0	2
P. sp	2	2	6	14	3	7	4	12	6	9	0	9	0	0
Microcachrydites antarcticus	22	10	17	14	13	5	3	15	10	25	4	25	0	22

Appendix 4 cont/

DH382 POLLEN SUM 3 REL.PERCENTAGE

UCP No.:	557s	558	559s	560s	561	562	563s	564	565s	566	567	568s	569	570	571s	572s	573s
DEPTH :	243.92	254.36	262.90	273.20	278.98	303.94	314.40	324.40	333.41	344.26	359.75	369.18	378.40	389.64	395.70	402,27	404.30
Phyllocladidites mawsonii	14	31	13	30	29	46	44	21	41	52	29	25	38	22	13	19	4
Phyllcladus paleogenicus	4	3	4	4	1	9	16	5	18	11	13	40	13	9	7	16	23
Podocarpidites cf. ellipticus	24	13	24	15	19	12	2	14	10	20	12	11	13	13	26	35	38
P. marwickii	14	6	8	10	6	10	8	14	8	7	20	3	0	5	15	3	9
P. sp A	1	7	8	10	10	4	6	13	4	0	5	11	0	11	4	3	11
P. sp	8	7	3	0	0	0	3	5	4	2	2	1	0	0	0	0	0
Microcachrydites antarcticus	35	32	41	30	35	20	21	29	16	9	19	10	38	40	35	23	15

DH387 POLLEN SUM 3 REL.PERCENT

UCP No.:	637s	636s	635s	634	632	631s
DEPTH :	117.01	114.68	112.68	104.29	86.96	74.41
Phyllocladidites mawsonii	42	29	18	13	33	29
Phyllolcadus paleogenicus	4	2	9	26	8	9
Podocarpidites cf. ellipticus	18	17	29	0	10	7
P. marwickii	10	18	11	22	18	16
P. sp A	1	4	0	4	9	14
P. sp	8	4	17	26	8	4
Microcachrydites antarcticus	17	25	17	9	16	21

DH375. POLLEN SUM 3 REL.PERCENT

UCP No.:	628s	627s	626	625s	624s	623s	622s	621s	620
DEPTH :	445.86	434.86	425.78	416.79	412.77	409.46	395.01	380.11	368.02
Phyllocladidites mawsonii	23	58	23	16	47	60	33	49	46
Phyllolcadus paleogenicus	8	7	4	14	1	1	16	7	4
Podocarpidites cf. ellipticus	8	4	13	21	9	4	7	9	8
P. marwickii	16	5	23	16	12	12	5	4	8
P. sp A	16	9	5	12	6	6	7	4	2
P. sp	1	8	3	5	6	4	10	0	7
Microcachrydites antarcticus	28	9	28	16	19	13	22	26	25

APPENDIX 5 SAMPLE CODE NUMBER SYSTEM

UCP No. = University Canterbury Palynology Number
Lab No. = Laboratory number used in processing
Depth(m) = Depth of sample in drillhole

* Beaumont Coal Measures
# New Brighton Conglomerate

UCP No.	Lab No.	Depth(m)	UCP No.	Lab No.	Depth(m)	UCP No.	Lab No.	Depth(m)
Drillhole 335			563	7c	314.40	605	5f	153.30
518	1a	222.70*	564	8c	324.40	606	6f	183.70
519	2a	230.60	565	9c	333.41	607	7f	196.40
520	3a	242.36	566	10c	344.26	608	8f	272.65
521	4a	250.70	567	11c	359.75	609	9f	283.90
522	5a	263.92	568	12c	369.18	610	10f	299.89#
523	6a	272.72	569	13c	378.40	611	11f	330.86#
524	7a	284.10	570	14c	389.40	612	12f	362.45#
525	8a	291.85	571	15c	395.70	613	13f	371.50#
526	9a	299.00	572	16c	402.27	614	14f	382.40#
527	10a	305.52	573	17c	404.30	615	15f	392.10#
528	11a	314.29	Drillhole 347			616	16f	400.70#
529	12a	324.34	574	1d	144.60	617	17f	409.00#
530	13a	334.40	575	2d	150.00	Drillhole 375		
531	14a	344.71	576	3d	160.65	618	1g	315.32*
532	15a	351.18	577	4d	174.85	619	2g	346.00*
533	16a	364.74	578	5d	205.15	620	3g	368.02
534	17a	374.35	579	6d	208.40	621	4g	380.11
535	19a	203.38*	580	7d	216.40	622	5g	395.01
536	20a	208.00*	Drillhole 364			623	6g	409.46
Drillhole 336			581	1e	157.25*	624	7g	412.79
537	1b	153.00*	582	2e	162.80*	625	8g	416.79
538	2b	161.90*	583	3e	187.00*	626	9g	425.78
539	3b	187.82*	584	4e	197.50*	627	10g	434.86
540	4b	196.10*	585	5e	207.00*	628	11g	445.86
541	5b	209.25*	586	6e	217.00*	Drillhole 387		
542	6b	219.80	587	7e	227.25*	629	1h	33.41*
543	7b	230.11	588	8e	232.95*	630	3h	63.52*
544	8b	249.74	589	9e	281.70*	631	4h	74.41
545	9b	258.69	L12725/1		287.89	632	5h	86.96
546	10b	273.70	L12726/1		296.53	633	6h	90.83
547	11b	277.96	L12727/1		305.74	634	8h	104.29
548	12b	288.80	590	10e	313.60	635	9h	112.68
549	14b	309.69	591	11e	323.85	636	10h	114.68
550	15b	323.76	592	12e	332.30	637	11h	117.10
551	16b	337.20	593	13e	343.55	Drillhole 384		
552	17b	353.30	594	14e	353.80	638	1i	287.25*
553	18b	367.30	595	15e	358.00	639	2i	296.60*
554	19b	379.00	596	16e	375.40	640	3i	307.40*
555	20b	388.45	597	17e	381.50	641	4i	311.78*
556	21b	397.00	598	18e	411.30	642	5i	326.74*
Drillhole 382			599	19e	426.80	643	6i	331.93*
557	1c	243.92	600	20e	434.00	644	7i	338.97*
558	2c	254.36	Drillhole 343			645	8i	364.84*
559	3c	262.90	601	1f	102.84	646	9i	373.16*
560	4c	273.20	602	2f	114.90	647	10i	387.70*
561	5c	278.98	603	3f	123.44	648	11i	395.00
562	6c	303.94	604	4f	145.81	649	12i	414.20

PLATE 1

Magnification of grains is shown by the scale bar in the Figure 1 unless otherwise indicated.

FIGURE 1. *Trilites sp. D* Slide UCP 562; co-ords. 107.5/4.6

FIGURE 2. *Trilites sp. A* Slide UCP 547; co-ords. 104.7/2.3

FIGURE 3. *Trilites fragilis* Couper 1953. Slide UCP 544s; co-ords. 111.0/21.10

FIGURE 4. *Trilites sp. E* Slide UCP 592s; co-ords. 106.0/5.3

FIGURE 5. *Trilites morleyi* Couper 1953. Slide UCP 604s; co-ords. 104.3/20.0

FIGURE 6. *Trilites sinuatus* Couper 1953. Slide UCP 527; co-ords. 107.0/9.3

FIGURE 7. *Trilites ohaiensis* Couper 1953. Slide UCP 626; co-ords. 119.2 traverse

FIGURE 8. *Trilites cf. morleyi* Couper 1953. Slide UCP 622s; co-ords. 113.9/4.8

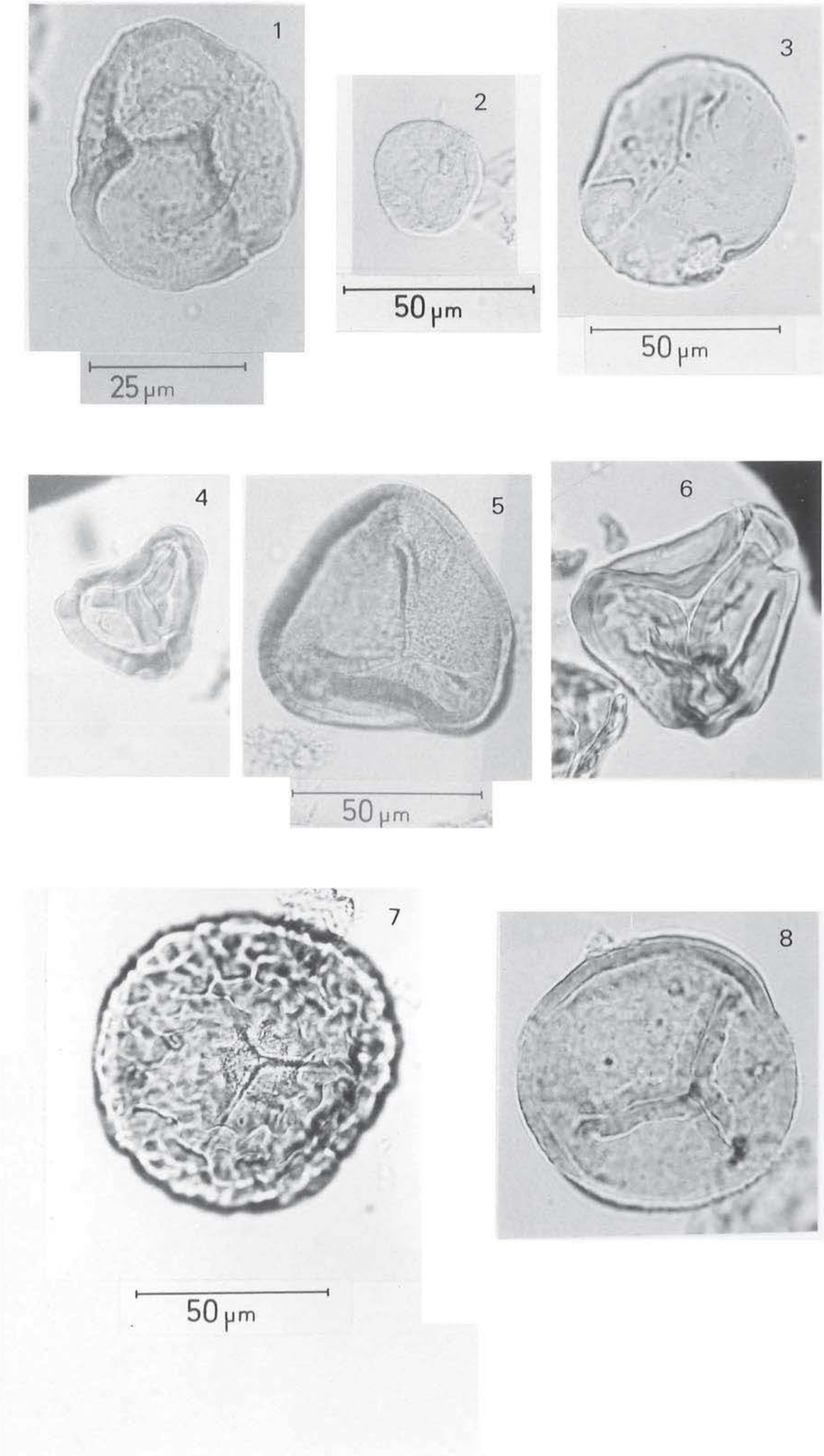

1
2
3
25 µm
50 µm
50 µm
4
5
6
50 µm
7
8
50 µm

PLATE 2

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Laevigatosporites ovatus* Wison and Webster 1946. Slide UCP 628s; co-ords. 115.2/4.7

FIGURE 2. *Laevigatosporites major* (Cookson) Krutzsch 1959. Slide UCP 628s; co-ords. 115.2/4.7

FIGURE 3. *Peromonolites bowenii* Couper 1953. Slide UCP 626; co-ords. 105.2/8.0

FIGURE 4. *Polypodiidites minimus* Couper 1960. Slide UCP 542s; co-ords. 102.4/13.5

FIGURE 5. *Polypodiidites cf. minimus* Couper 1960. Slide UCP 628s; co-ords. 110.0/3.0

FIGURE 6. *Verrucatosporites sp.* Raine. Slide UCP 623s; co-ords. 93.0/27.5

FIGURE 7. *Verrucatosporites sp.* Raine. Slide UCP 623s; co-ords. 109.9/23.3

FIGURE 8. *Polypodiidites sp. C* Slide UCP 550s; co-ords. 114.3/12.1

FIGURE 9. *Polypodiidites sp. D* Slide L12725/2 (NZGS collection); co-ords. 95.2/12.9

FIGURE 10. *Osmundacites wellmanii* Couper 1953. Slide UCP 541s; co-ords. 110.1/9.4

FIGURE 11. *Osmundacites sp. A* Slide UCP 559s; co-ords. 97.6/9.0

FIGURE 12. *Baculatisporites comaumensis* (Cookson) Potonie 1956. Slide UCP 628s; co-ords. f104.0/20.4

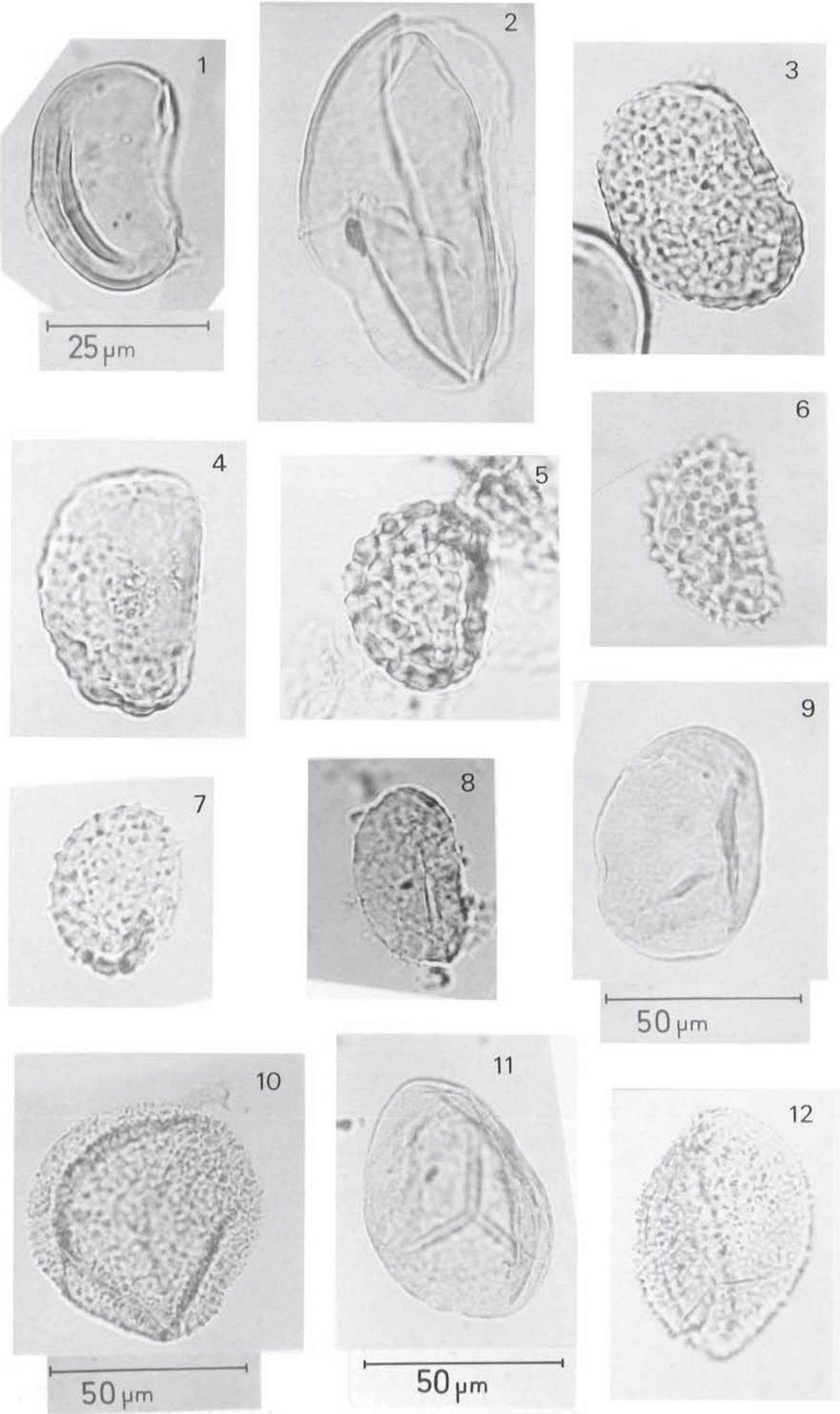

1
25 µm
2
3
4
5
6
7
8
9
50 µm
10
50 µm
11
50 µm
12

PLATE 3

Magnification of grains is shown by scale bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Trilites verrucatus* Couper 1953. Slide UCP 620; co-ords. 117.5/25.6

FIGURE 2. *Trilites cf. verrucatus* Couper 1953. Slide UCP 625s; co-ords. 119.2/5.9

FIGURE 3. *Clavifera rudis* Bolkhovitina. Slide UCP 592s; co-ords. 106.0/5.3

FIGURE 4. *Clavifera triplex* (Bolkovitina) Bolkovitina 1966. Slide UCP 626; co-ords. 117.2/first traverse

FIGURE 5. *Trilites cf. tuberculiformis* Cookson 1947. Slide UCP 626; co-ords. 120.4/4.4

FIGURE 6. *Leptolepidites verrucatus* Couper 1953. Slide UCP 555; co-ords. 109.4/20.3

FIGURE 7. *Lepolepidites major* Couper 1958. Slide UCP 628s; co-ords. 106.8/14.1

FIGURE 8. *Stereisporites antiquasporites* (Wilson and Webster) Dettman 1963. Slide UCP 626; co-ords. 110.1/22.4

FIGURE 9. *Stereisporites regium* (Drozhastichich) Drugg 1967. Slide UCP 555; DIC, co-ords. 107.3/14.5

FIGURE 10. *Stereisporotes sp. A* Slide UCP 567; co-ords. 104.5/14.1

FIGURE 11. *Cingutriletes clavus* (Balme) Dettman 1963. Slide UCP 567; DIC, co-ords 104.5/14.1

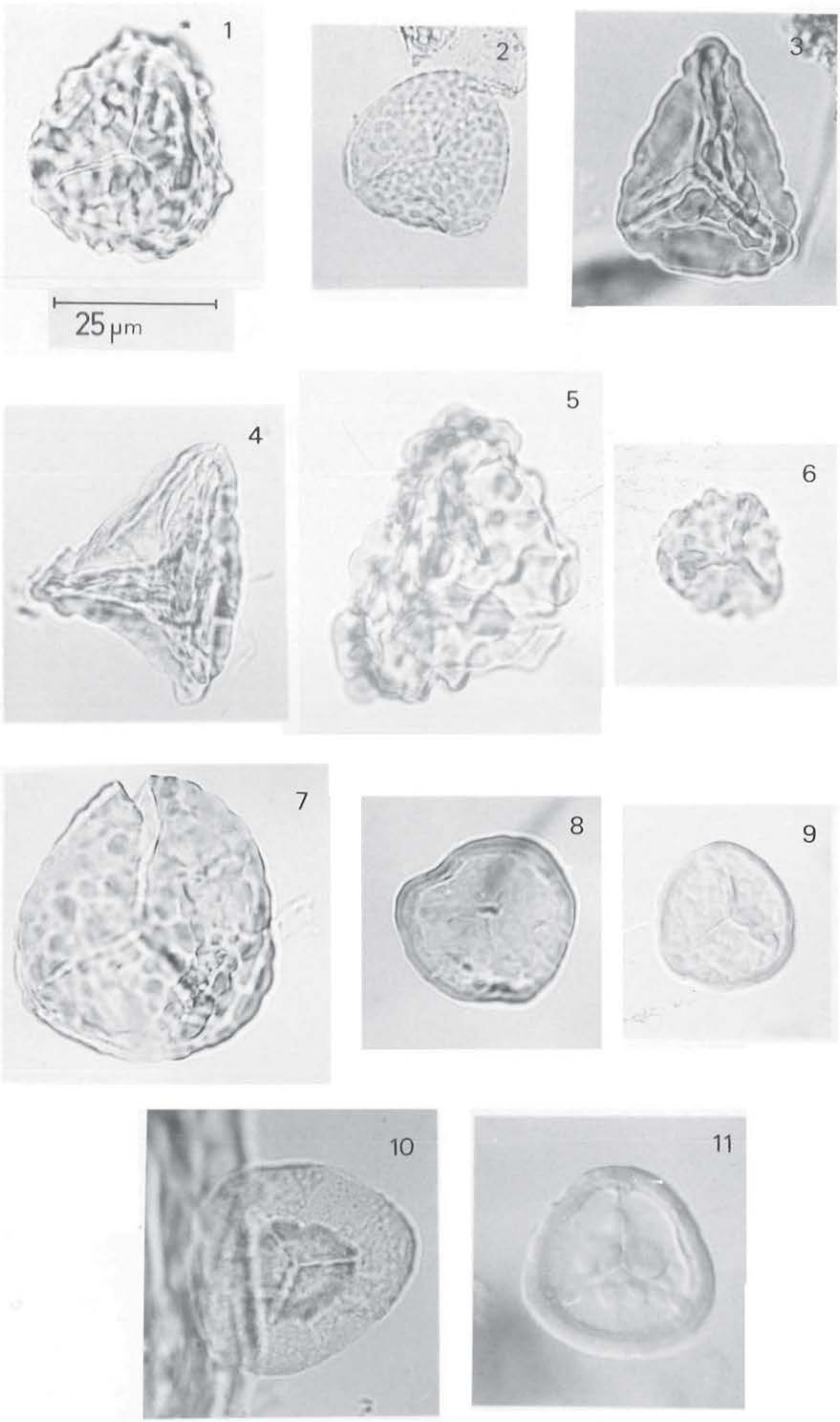

1
2
3
25 µm
4
5
6
7
8
9
10
11

PLATE 4

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated

FIGURE 1. *Lycopodium sp. (fastigiatum-volubile* group). Couper 1953. Slide UCP 628s; co-ords. 111.8/8.0

FIGURE 2. *Lycopodium fastigoides* Couper 1953. Slide UCP 624s; co-ords. 112.1/18.4

FIGURE 3. *Lycopodium sp. B* Slide UCP 620; co-ords. 109.5/5.1

FIGURE 4. *Lycopodium sp. A* Slide UCP 624s; co-ords. 117.8/5.5

FIGURE 5. *Aequitiradites cf. spinulosus* Cookson and Dettman 1961. Slide UCP 560s; co-ords 108.1/8.5

FIGURE 6. *Kraeuselisporites cf. majus* Cookson and Dettman 1963. Slide UCP 616; co-ords 98.8/22.2

FIGURE 7. *Camaronosporites cf. australiensis* Burger 1973. Slide UCP 626; co-ords. 97.6/in nail varnish

FIGURE 8. *Gleicheniidites cercinidites* Cookson 1953. Slide UCP 626; co-ords. 97.5/9.8

FIGURE 9. *Cyathidites minor* Couper 1953. Slide UCP 627s; co-ords. 101.1/17.2

FIGURE 10. *Ceratosporites equalis* Cookson and Dettman 1958. Slide UCP 628s; DIC, co-ords. 117.2/10.5

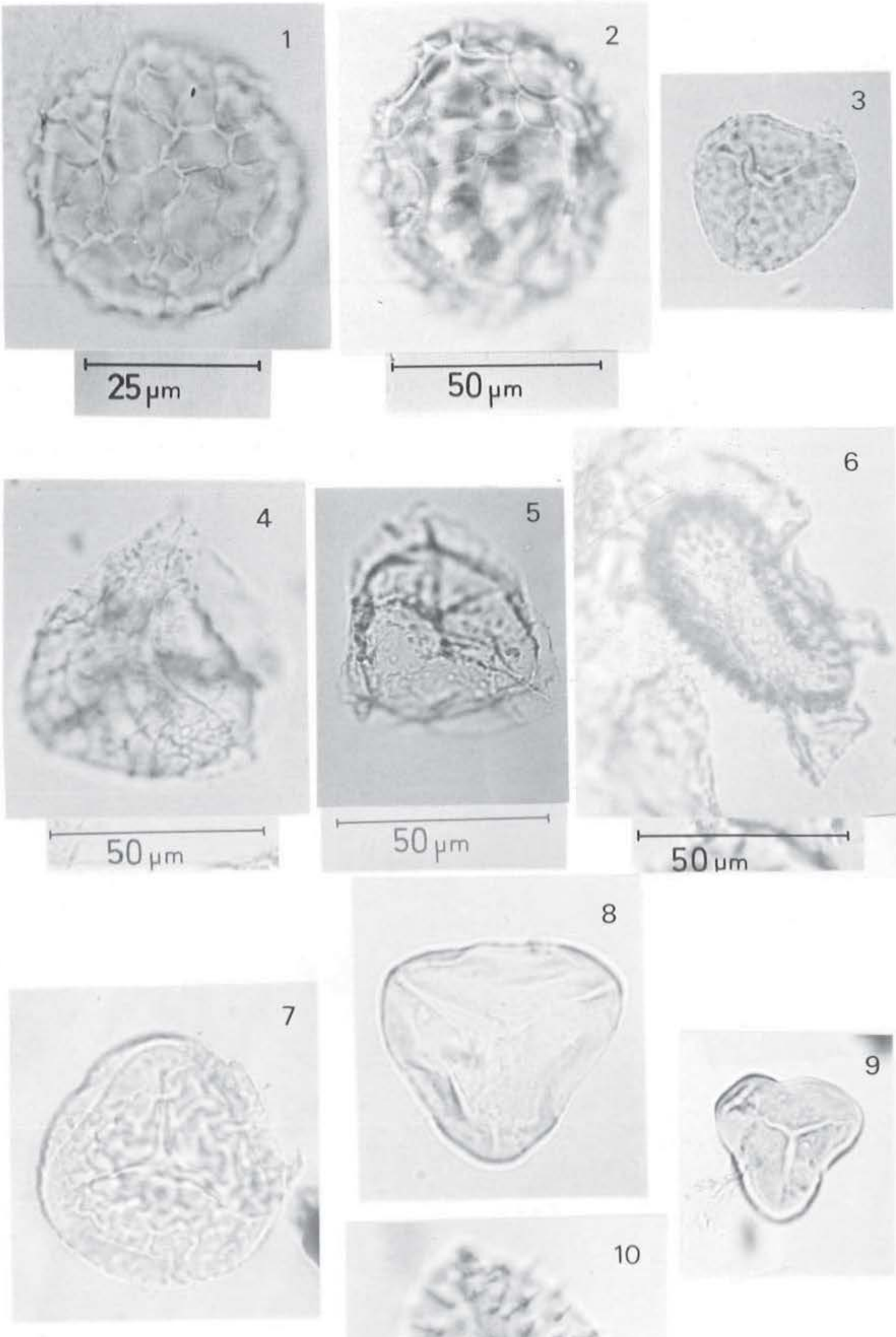

1
2
3
25 µm
50 µm
4
5
6
50 µm
50 µm
50 µm
7
8
9
10

PLATE 5

Magnification of grains is shown by the sacle bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Podocarpidites cf. ellipticus* Cookson 1947. Slide UCP 628s; co-ords. 2.3 traverse, close to 112.4

FIGURE 2. *Podocarpidites major* Couper 1953. Slide UCP 628s; co-ords. 105.6/19.5

FIGURE 3. *Microcachrydites antarcticus* Cookson 1947. Slide UCP 626; co-ords. 109.9/4.4

FIGURE 4. *Podocarpidites sp. A* Slide UCP 628s; co-ords f10.32***

FIGURE 5. *Podocarpidites marwickii* Couper 1953. Slide UCP 626; DIC, co-ords. 106.2/3.5

FIGURE 6. *Podosporites microsaccatus* (Couper). Slide UCP 627s; co-ords. 96.8/6.4

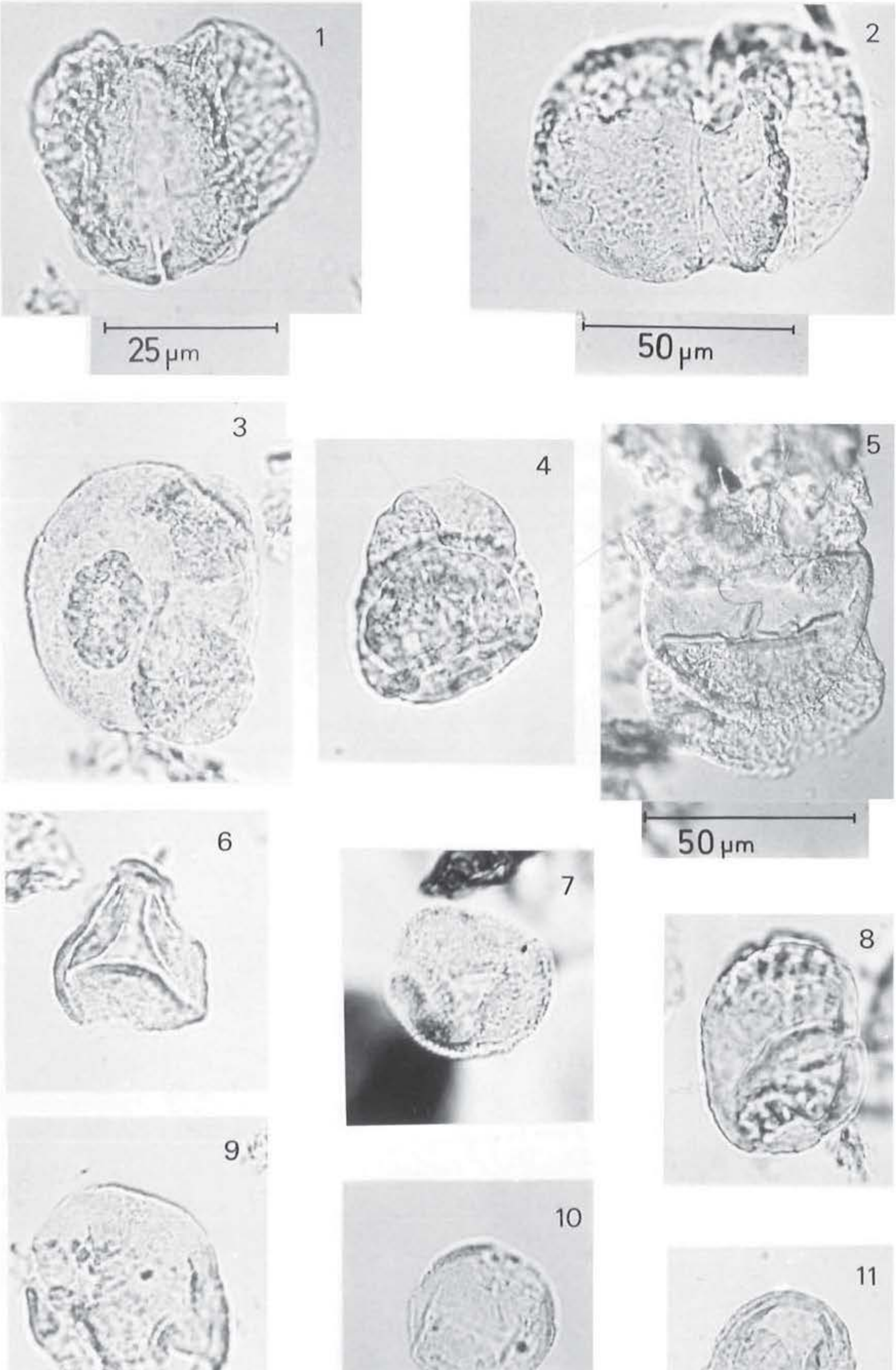
FIGURE 7. *Podosporites sp. A* Slide UCP 622s.

FIGURE 8. *Dacrydium prae-cupressinoides* Couper 1953. Slide UCP 623s; co-ords. 97.5/16.1

FIGURE 9. *Araucariacites australis* Cookson 1947. Slide UCP 624s

FIGURE 10. *Araucariacites sp.* Slide UCP 619s; co-ords. 111.0/26.9

FIGURE 11. *Phyllocladidites mawsonii* Cookson 1947. Slide UCP 628s; co-ords. 105.0/11.5



1
2
25 µm
50 µm
3
4
5
50 µm
6
7
8
9
10
11
50 µm

PLATE 6

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Phyllocladus paleogenicus* (Cookson) sensu Harris 1965. Slide UCP 628s; co-ords. 114.0/6.4

FIGURE 2. *Ephedra notensis* Cookson 1957. Slide UCP 623s; co-ords. f17.11

FIGURE 3. *Proteacidites retiformis* Couper 1960. Slide UCP 530; co-ords. 104.6/12.0

FIGURE 4. *Gambierina rudata* Stover 1973. Slide UCP 623s; co-ords. 98.6/12.5

FIGURE 5. *Proteacidites palisadus* Couper 1953. Slide UCP 626; co-ords. 102.8/23.2

FIGURE 6. *Proteacidites subpalisadus* Couper 1953. Slide UCP 627s; co-ords. 112.2/14.5

FIGURE 7. *Proteacidites scaboratus* Couper 1960. Slide UCP 628s; co-ords. 115.2/11.5

FIGURE 8. *Proteacidites cf. amolosexinus* Playford and Dettman 1968. Slide UCP 559s; co-ords. 103.7/16.3

FIGURE 9. *Proteacidites sp. A* Slide UCP 621; co-ords. 100.3/18.5

FIGURE 10. *Proteacidites sp. B* Slide UCP 555; co-ords. 119.6/14.4

FIGURE 11. *Proteacidites sp. C* Slide UCP 549s; DIC, co-ords. 96.0/19.2

FIGURE 12. *Proteacidites sp. D* Slide UCP 555; co-ords. 103.2/15.2

FIGURE 13. *Proteacidites sp. G* Slide UCP 532, DIC.

FIGURE 14. *Proteacidites sp.* Slide UCP 628s;

FIGURE 15. *Proteacidites sp.* Slide UCP 628s; co-ords. 112.4/2.3

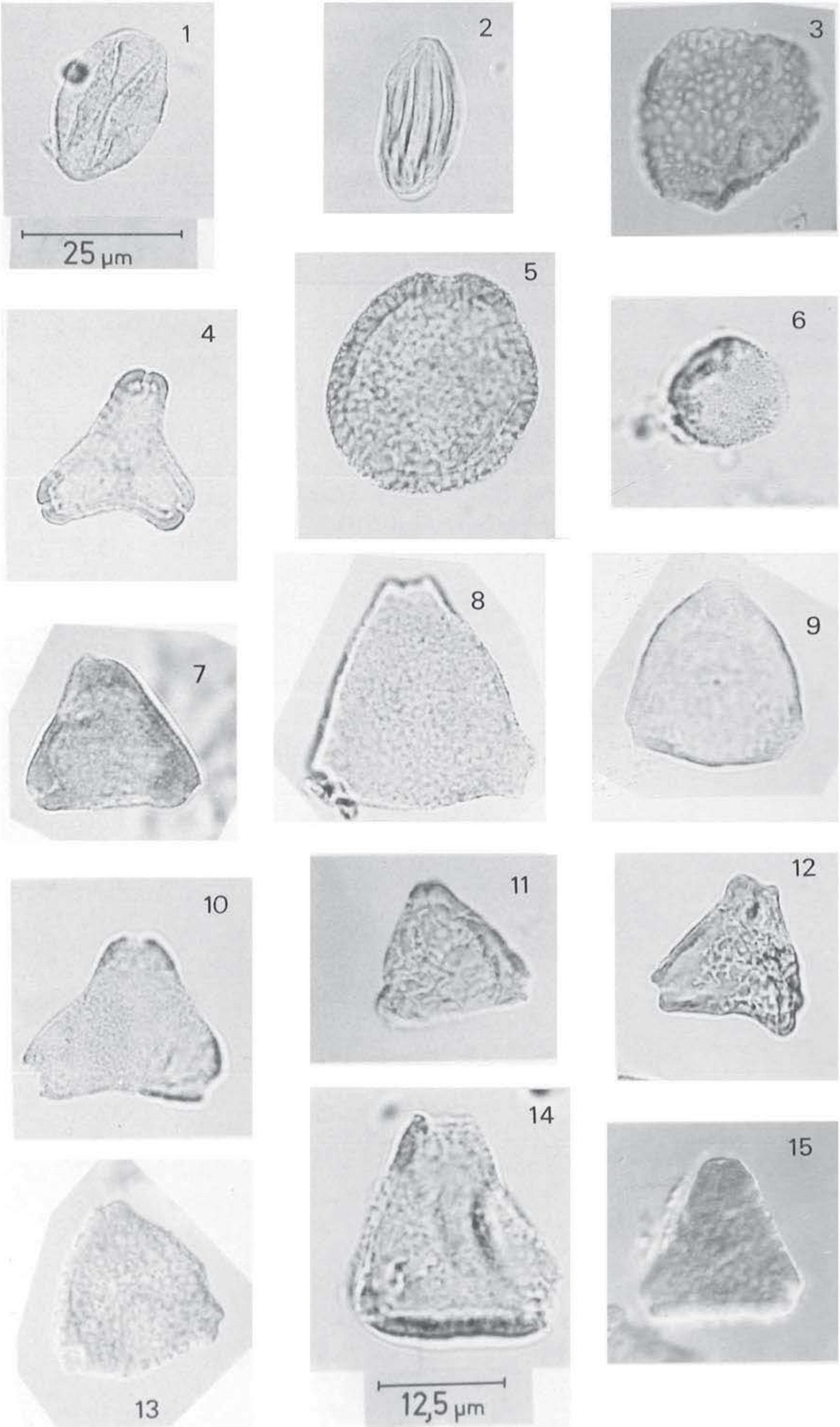

1
2
3
25 µm
4
5
6
7
8
9
10
11
12
13
14
15
12,5 µm

PLATE 7

Magnification of grains is shown by scale bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Proteacidites sp.* Slide UCP 628s; co-ords. 109.4/10.4

FIGURE 2. *Triorites minor* Couper 1953. Slide UCP 618s; co-ords. 112.3/10.7

FIGURE 3. *Beaupreadites sp.* Slide UCP 548; co-ords. 102.2/21.8

FIGURE 4. *Triorites fragilis* Couper 1953. Slide UCP 542s; co-ords. 100.4/17.0

FIGURE 5. *Triorites cf. fragilis* Couper 1953. Slide UCP 627s; co-ords. 103.3/6.4

FIGURE 6. *Triorites sp. C* Slide UCP 541s; co-ords. 116.0/9.9

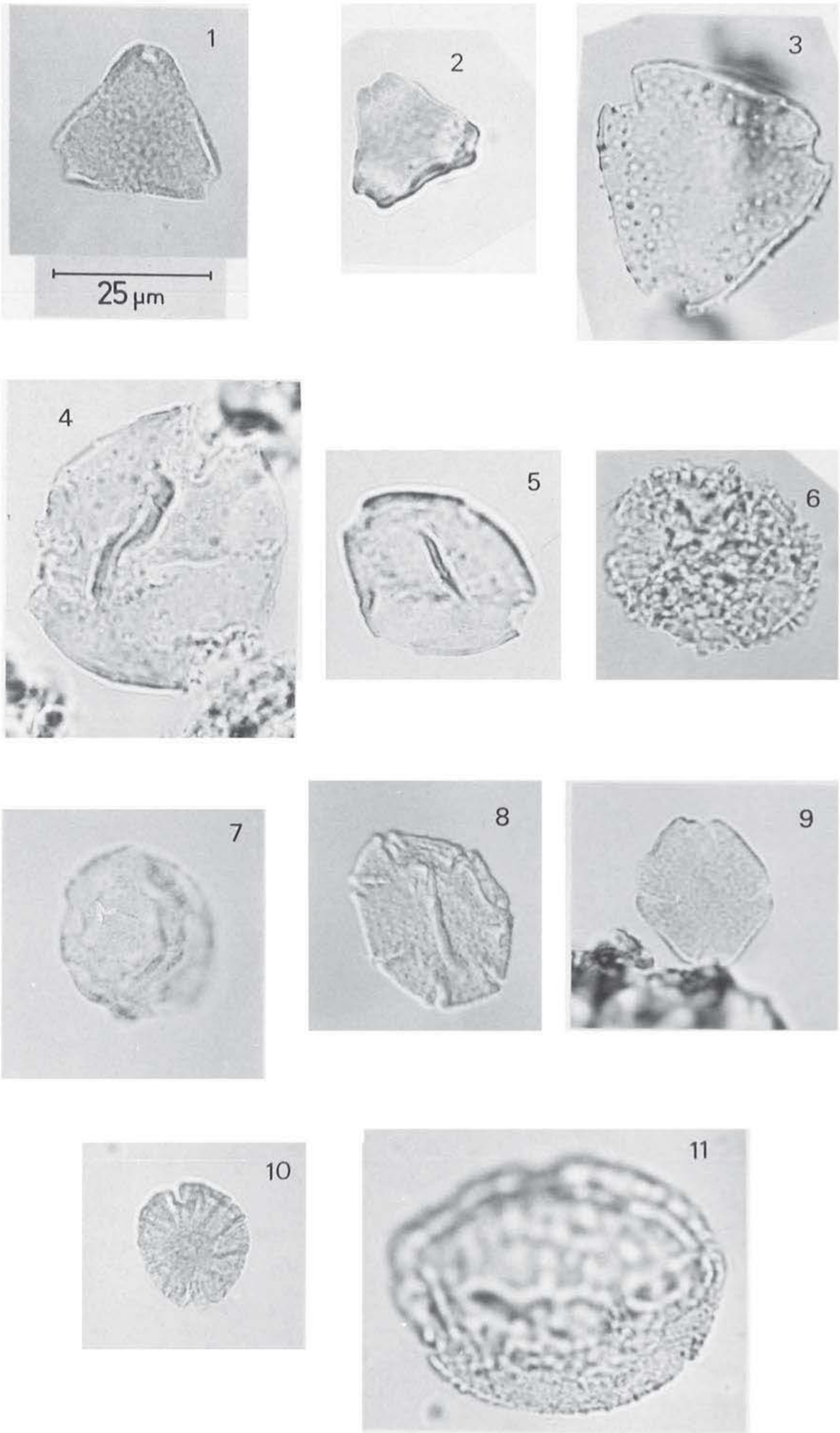
FIGURE 7. *Caryophyllidites polyoratus* Couper 1960. Slide UCP 628s; co-ords. 117.3/8.9

FIGURE 8. *Nothofagus kaitangata* Te Punga 1947. Slide UCP 628s; DIC, co-ords. 106.1/1.0

FIGURE 9. *Tetracolpites sp. O* Slide UCP 628s; co-ords. f12.24

FIGURE 10. *Polycolpites clavatus* Couper 1953. Slide UCP 628s

FIGURE 11. *Liliacidites intermedius* Couper 1953. Slide UCP 627s; co-ords. 115.6/10.7



1
25 μm
2
3
4
5
6
7
8
9
10
11

PLATE 8

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated.

FIGURE 1. *Liliacidites variegatus* Couper 1953. Slide UCP 628s; co-ords. 112.4-115.0/2.3

FIGURE 2. *Liliacidites sp. A* Slide UCP 555; co-ords. 106.2/16.6

FIGURE 3. *Liliacidites sp. C* Slide UCP 552s; co-ords. 106.0/6.1

FIGURE 4. *Liliacidites sp. D* Slide UCP 631s; co-ords. 112.7/19.6

FIGURE 5. *Monosulcites granulatus* Couper 1960. Slide UCP 628s; co-ords. 110.4/4.7

FIGURE 6. *Monosulcites "subgranulatus"* Slide UCP 565; co-ords. 105.5/17.5

FIGURE 7. *Monosulcites cf. minimus* Couper 1953. Slide UCP 619s; co-ords. 110.5/8.5

FIGURE 8. *Monosulcites sp. A* Slide UCP 555; co-ords. 155.3/18.1

FIGURE 9. *Monosulcites sp. B* Slide UCP 625s; co-ords. 101.9/22.3

FIGURE 10. *Monosulcites sp. C* Slide UCP 625s; co-ords. 121.2/14.9

FIGURE 11. *Monosulcites sp. D* Slide UCP 625s; co-ords. 115.7/14.5

FIGURE 12. *Monosulcites sp. E* Slide UCP 543s; co-ords. 102.3/11.2

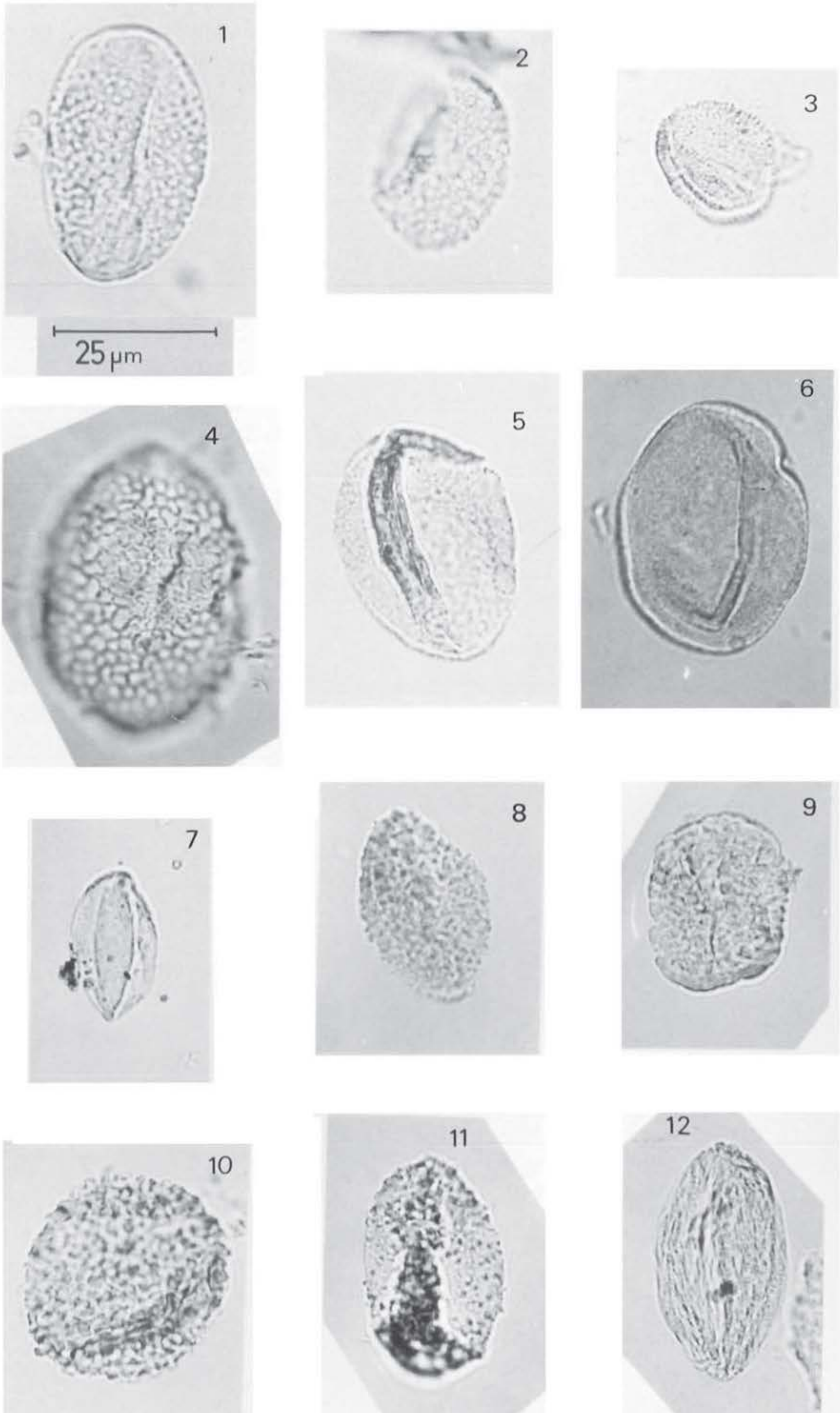

1
2
3
25 μm
4
5
6
7
8
9
10
11
12

PLATE 9

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated.

FIGURE 1 : *Monosulcites sp. H* Slide UCP 623s

FIGURE 2 : *Monosulcites sp. I* Slide UCP 536s

FIGURE 3 : *Monosulcites sp. J* Slide UCP 634; co-ords. 112.8/1.7

FIGURE 4 : *Monosulcites sp. K* Slide UCP 634; co-ords. 106.8/1.8

FIGURE 5 : *Monosulcites sp. M* Slide UCP 590s; co-ords. 102.8/4.7

FIGURE 6 : *Tricolpites lilliei* Couper 1953. Slide UCP 626; co-ords. 26.4

FIGURE 7 : *Tricolpites gillii* Cookson 1956. Slide UCP 628s; co-ords. approx 103.6/22.4

FIGURE 8 : *Tricolpites cf. pachyexinus* Couper 1953. Slide UCP 545; co-ords. 114.3/15.5

FIGURE 9 : *Tricolpites reticulatus* Cookson 1947. Slide UCP 628s; co-ords. 100.1/5.5

FIGURE 10 : *Tricolpites sp. B* Slide UCP 624s; co-ords. 104.1/9.2

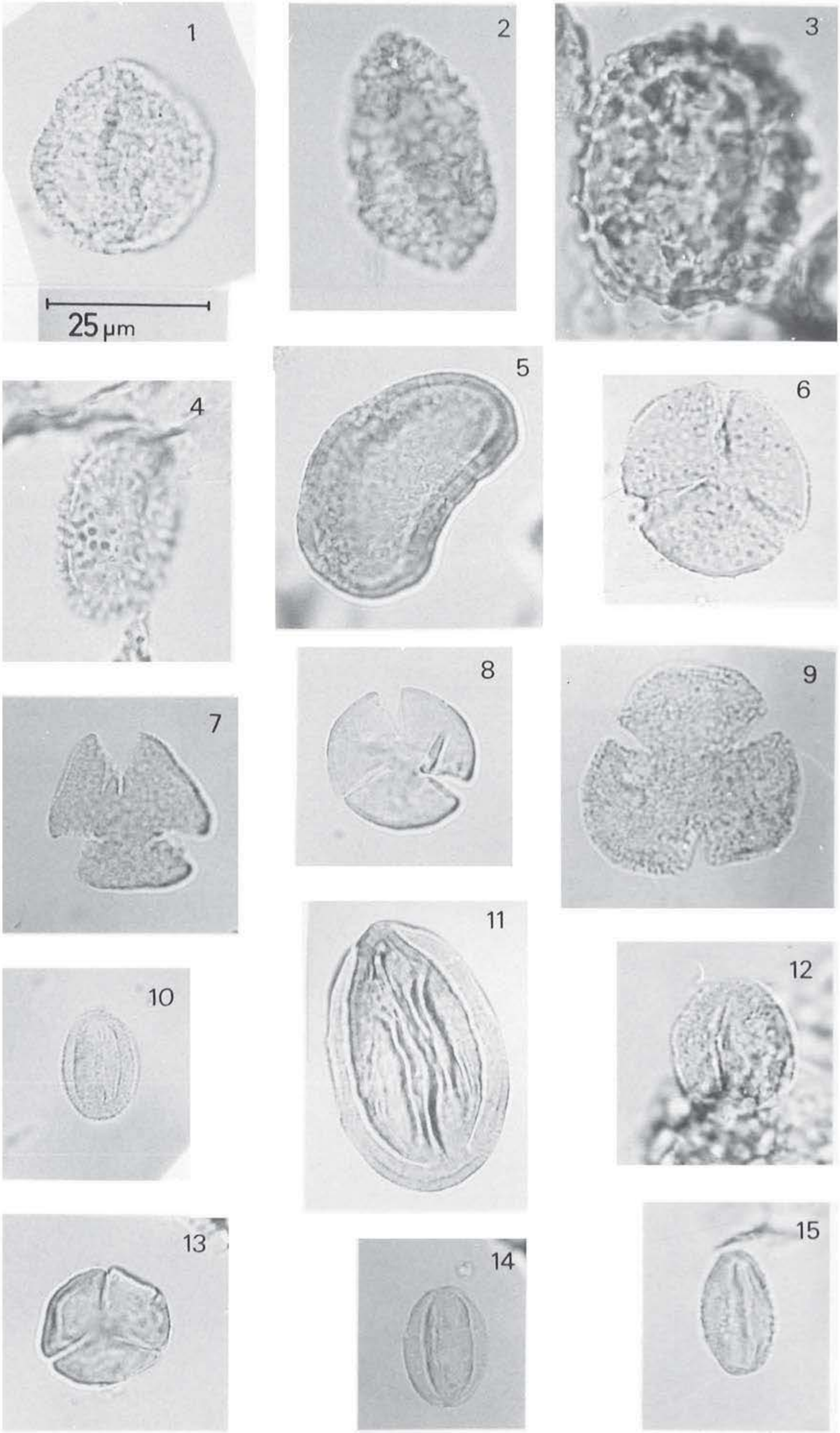
FIGURE 11 : *Tricolpites sp. C* Slide UCP 524s; co-ords. 110.7/11.5

FIGURE 12 : *Tricolpites sp. D* Slide UCP 625s; co-ords. 118.3/14.5

FIGURE 13 : *Tricolpites sp. E* Slide UCP 626; co-ords. 108.3/?

FIGURE 14 : *Tricolpites sp. F* Slide UCP 625s; co-ords. 7.5/?

FIGURE 15 : *Tricolpites sp. G* Slide UCP 628s; co-ords. unknown


1
2
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25 μm
4
5
6
7
8
9
10
11
12
13
14
15

PLATE 10

Magnification of grains is shown by the scale bar in Figure 1 unless otherwise indicated.

FIGURE 1 : *Tricolpites sp. J* Slide UCP 628s; DIC, co-ords 98.4/4.7

FIGURE 2 : *Tricolpites sp. K* Slide UCP 559s; co-ords. 109.7/11.4

FIGURE 3 : *Tricolpites sp. L* Slide UCP 546; co-ords. 110.1/7.4

FIGURE 4 : *Tricolpites sp. M* Slide UCP 545s; co-ords. 117.0/11.1

FIGURE 5 : *Tricolpites sp. N* Slide UCP 620; co-ords. 119.5/25.1

FIGURE 6 : *Tricolpites sp. O* Slide UCP 628s; co-ords. 108.4/11.5

FIGURE 7 : *Tricolpites sp. Q* Slide UCP 522s; co-ords. 101.9/8.8

FIGURE 8 : *Tricolpites sp. W* Slide UCP 622s; co-ords. 97.7/20.0

FIGURE 9 : *Tricolpites sp. Z* Slide UCP 533; co-ords. 112.5/10.0

FIGURE 10 : *Tricolporites sp. B* Slide UCP 621; co-ords. 112.0/26.7

FIGURE 11 : *Tricolpites sp. Y* Slide UCP 590s; co-ords. 106.8/4.4

FIGURE 12 : *Tricolporites sp. C* Slide UCP 621; co-ords. 119.10/27.8

FIGURE 13 : *Tricolporites sp. E* Slide UCP 621; co-ords. 166.5/27.5

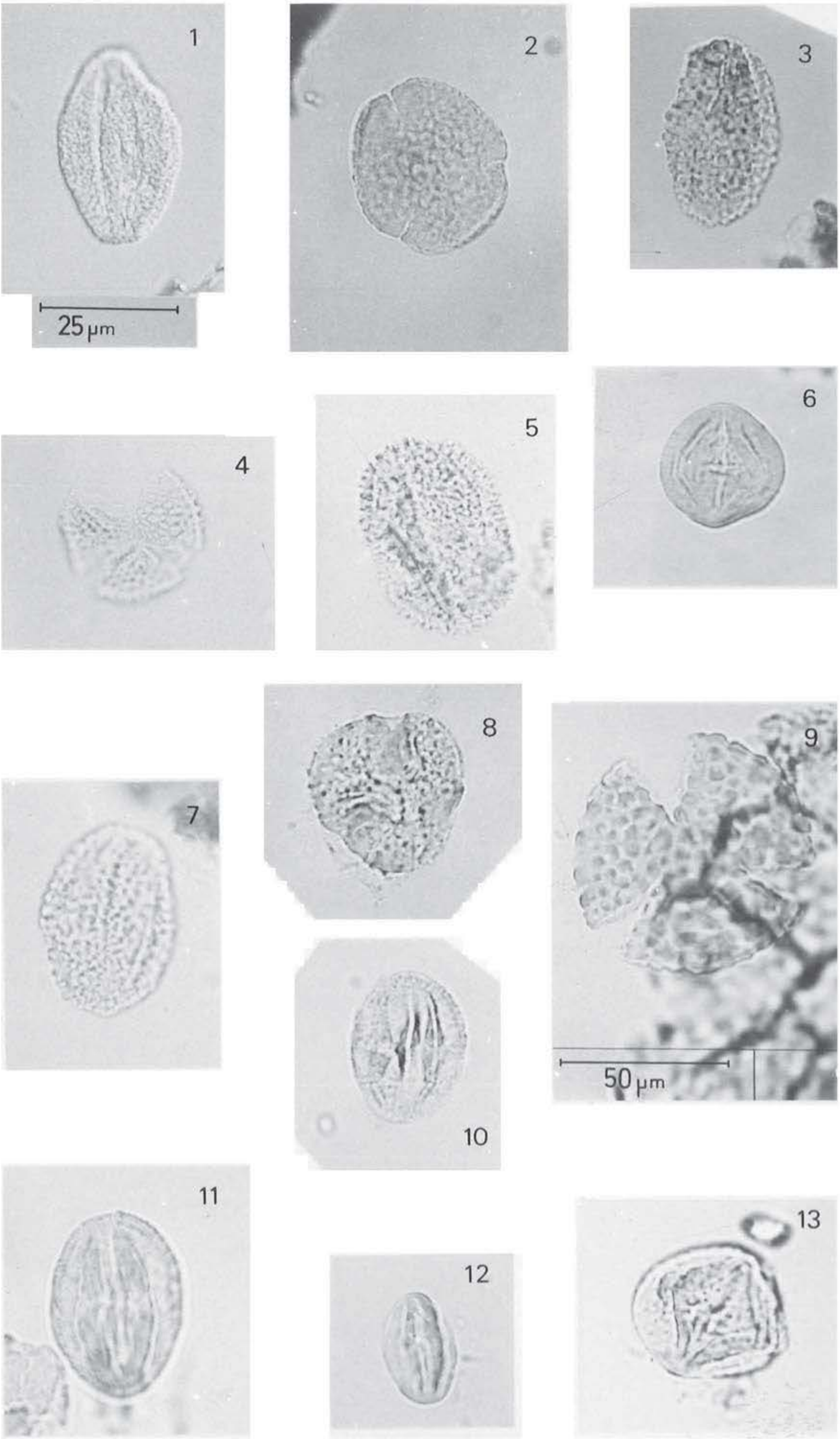

1
25 µm
2
3
4
5
6
7
8
9
50 µm
10
11
12
13

diagram to accompany thesis by M.C. Warnes

Figure 12a : Distribution of species in drillhole 387 in order of first appearance

"Palynology of Ohai Coalfield, Southland".

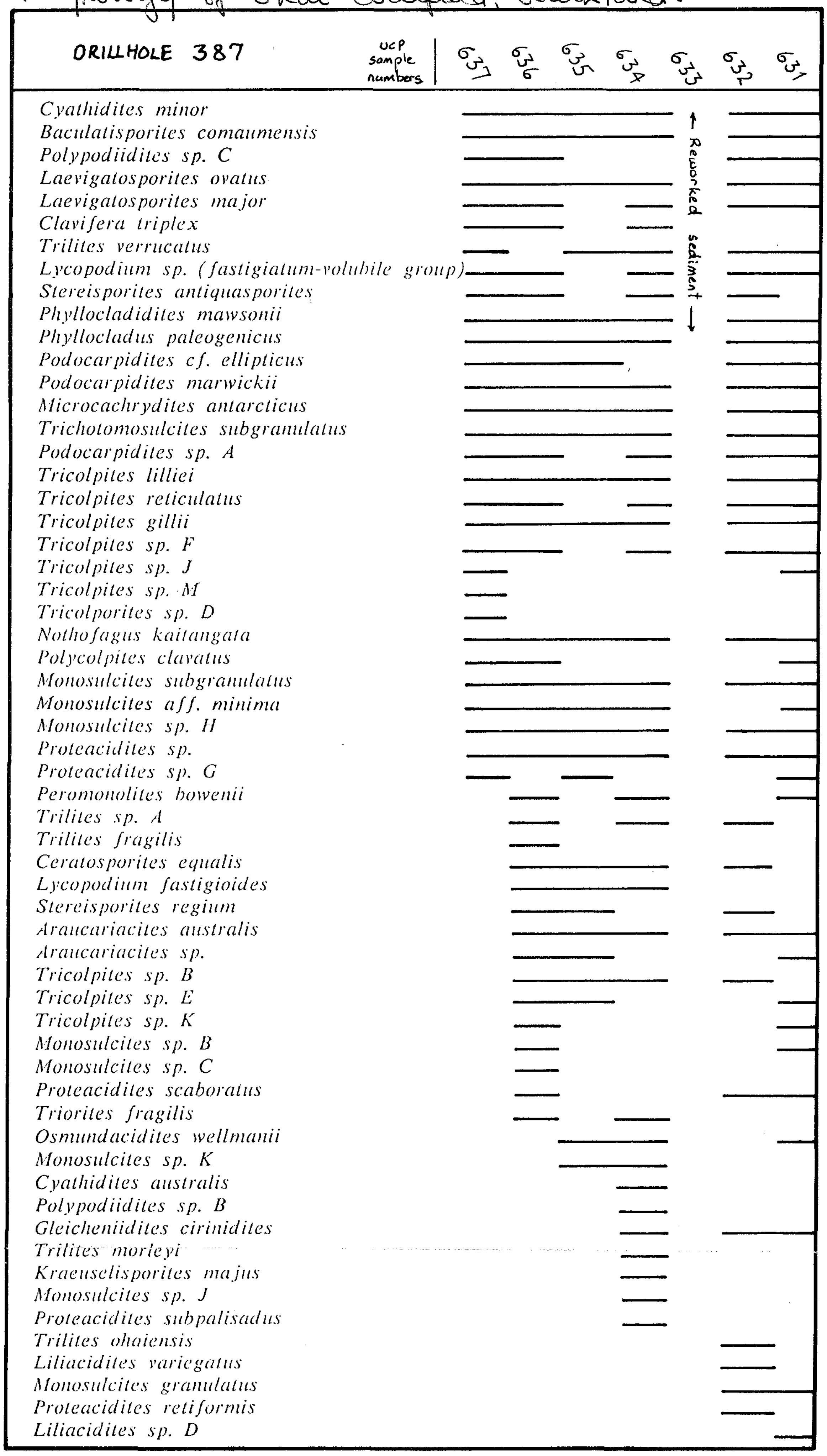


diagram to accompany thesis by M.C. Warnes
"Palynology of Ohai Coalfield, Southland"

Figure 12b : Distribution of species in drillhole 347 in order of first appearance

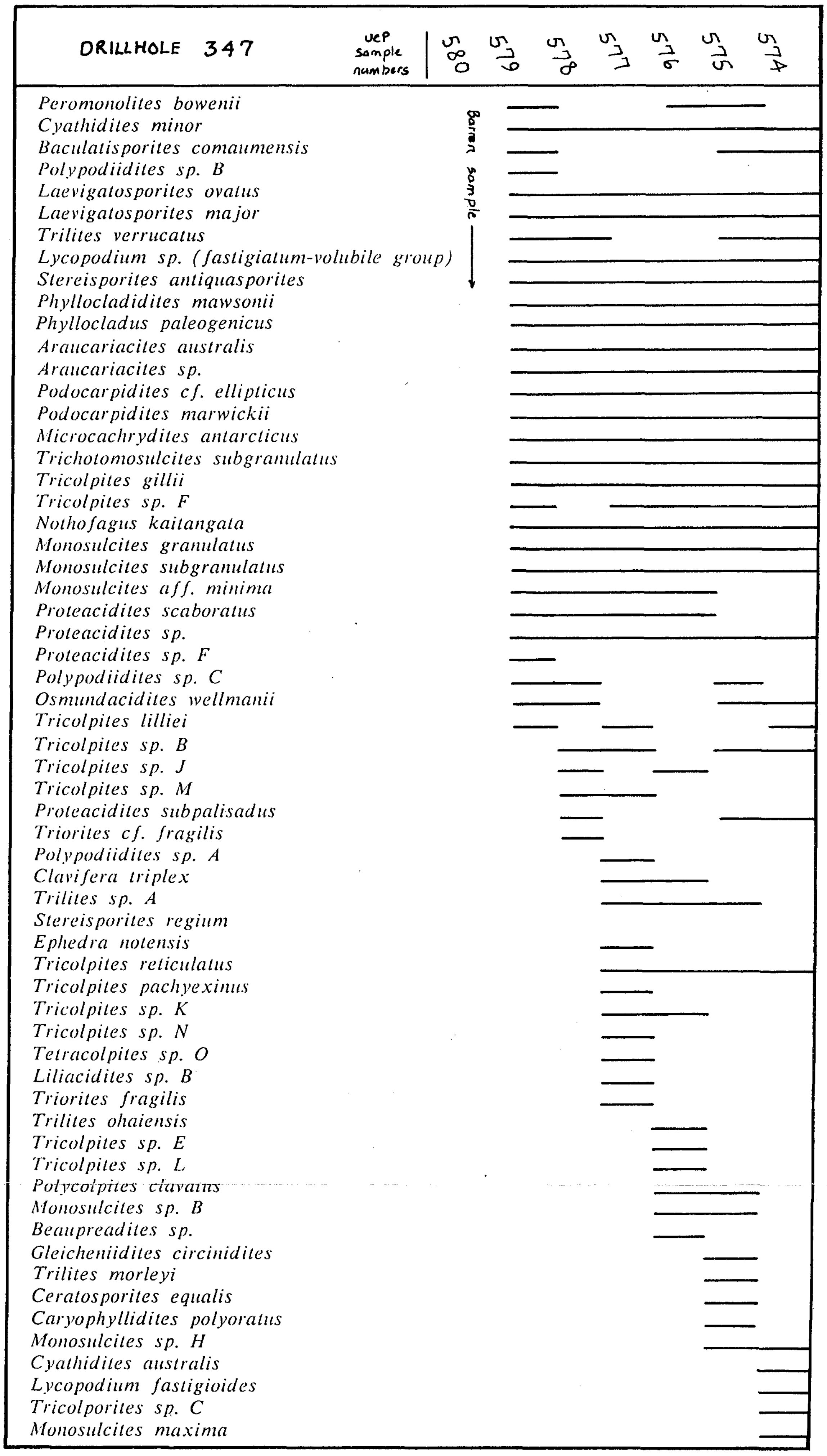


Figure 12c : Distribution of species in drillhole 343 in order of first appearance

diagram to accompany thesis by M.C. Warnes

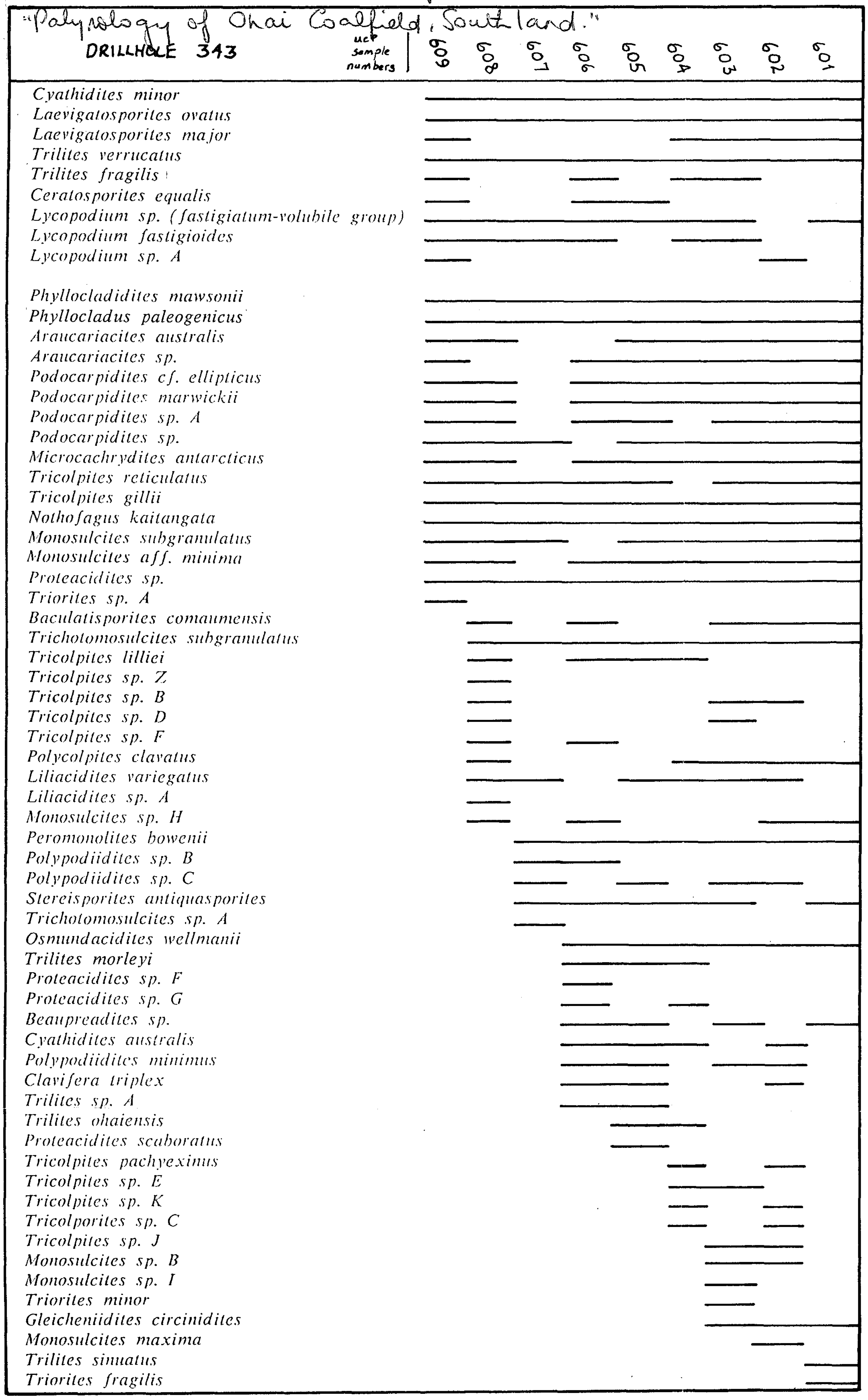


diagram to accompany thesis by M.C. Warnes
"Palynology of Ohai Coalfield, Southland"

Figure 12d : Distribution of species in drillhole 364 in order of first appearance

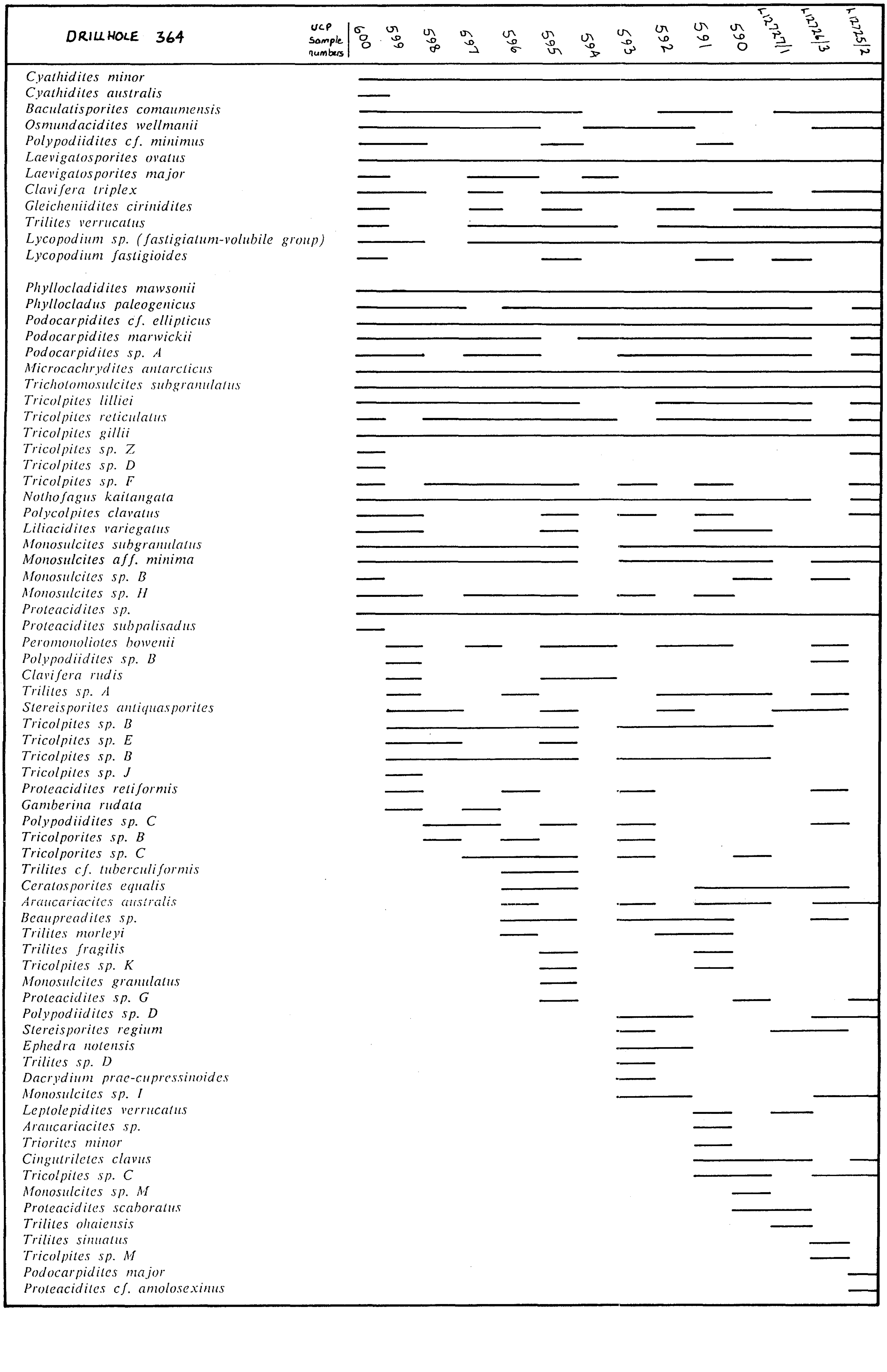


diagram to accompany thesis by M.C. Warnes
"Palynology of Ohai Coalfield, Southland."

Figure 12e : Distribution of species in drillhole 335 in order of first appearance

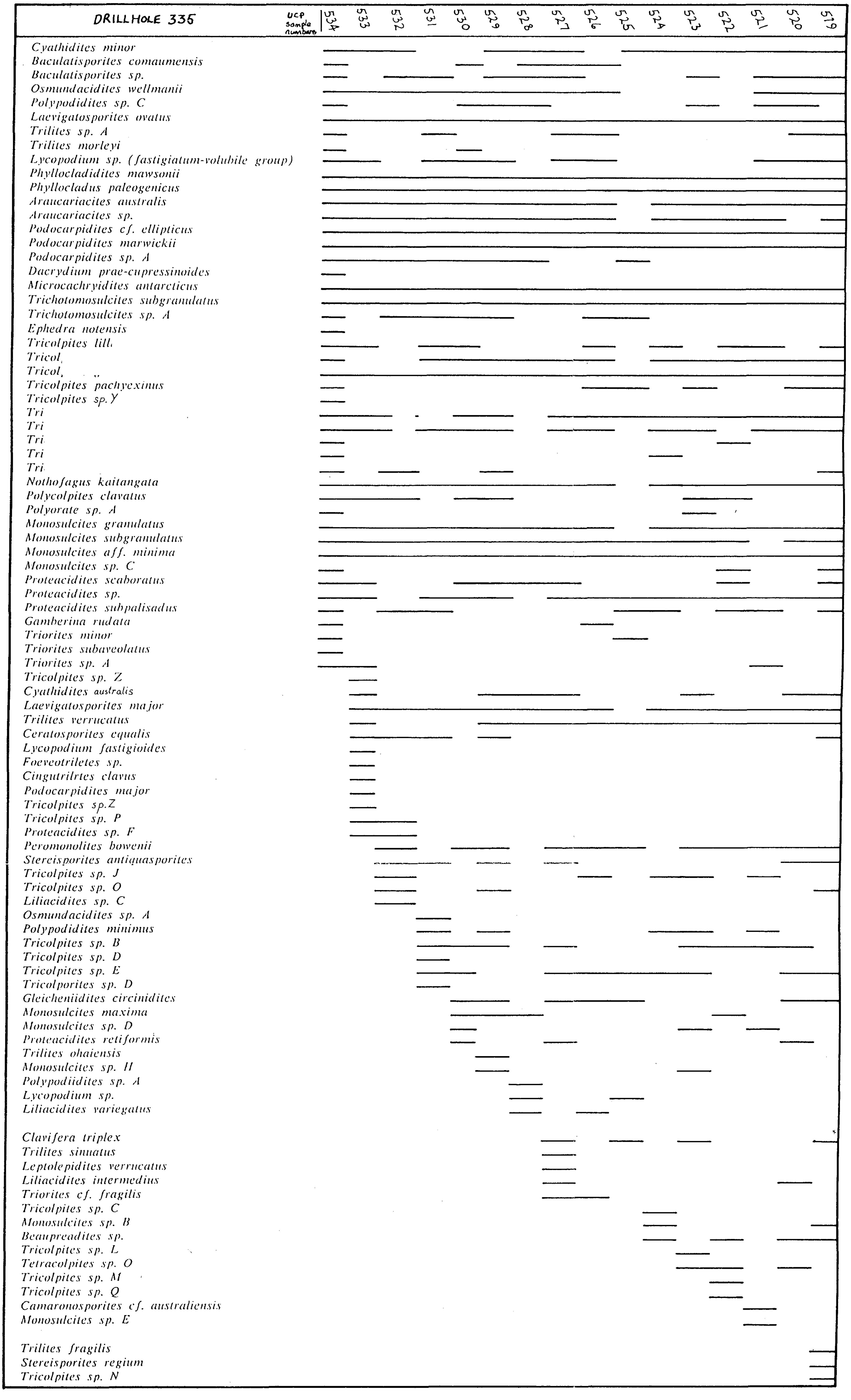
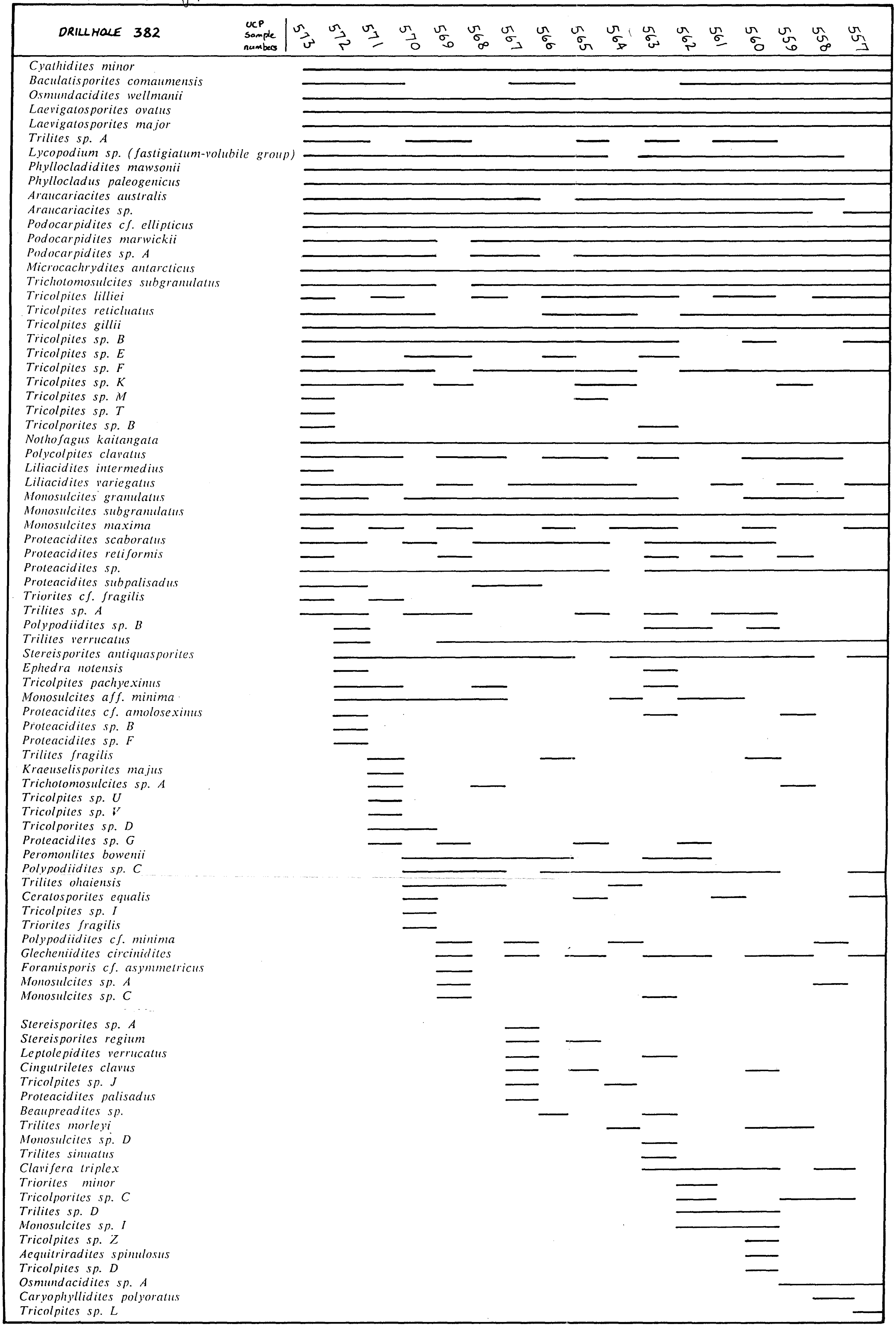


diagram to accompany thesis by M.C. Warnes "Palynology of Ohai Coalfield, Southland."

Figure 12f : Distribution of species in drillhole 382 in order of first appearance



diagrams to accompany thesis by M.C. Warnes
"Palynology of Ohai Coalfield, Southland"

Figure 12g : Distribution of species in drillhole 336 in order of first appearance

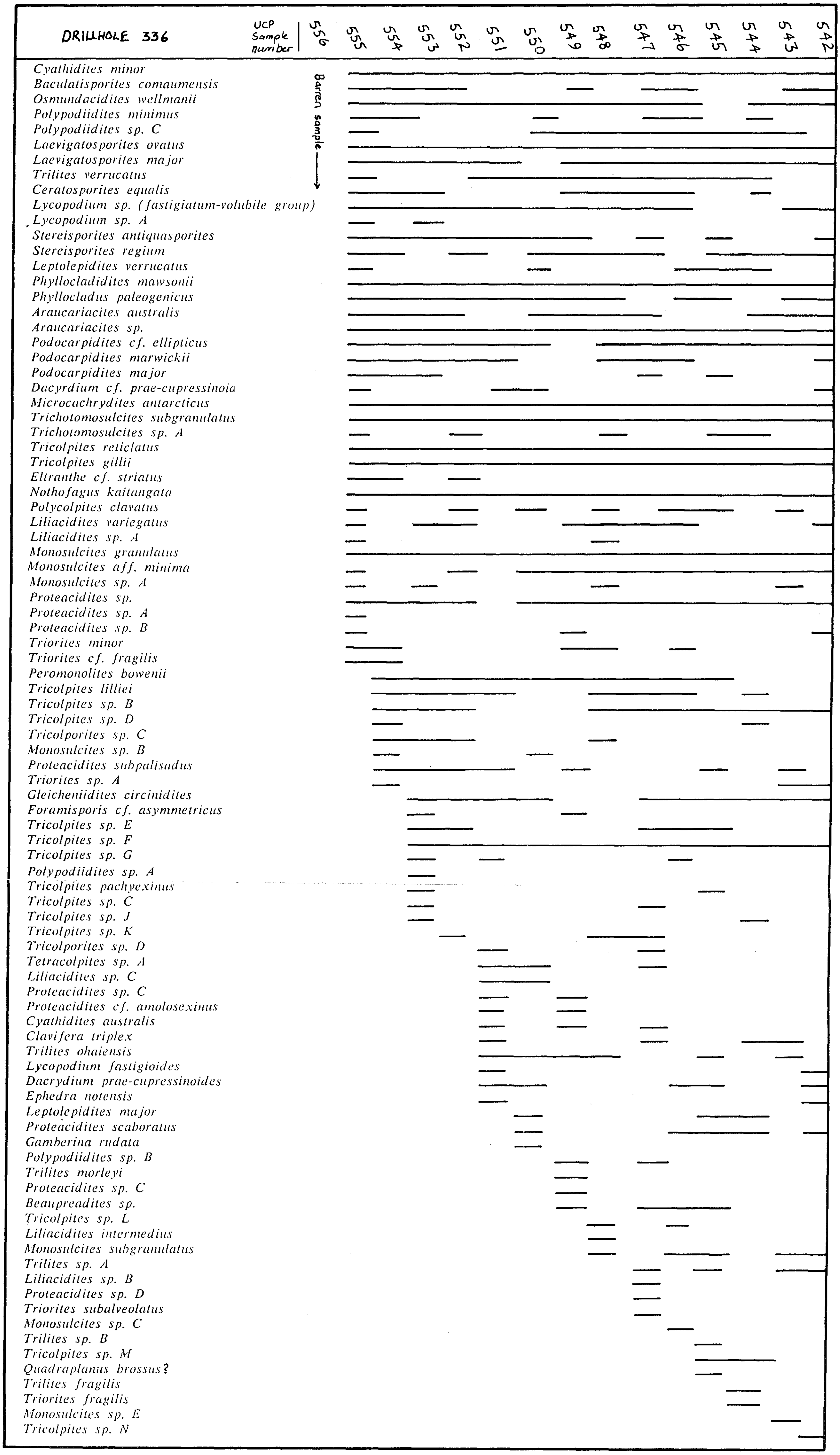


diagram to accompany thesis by M.C. Watnes

Figure 12h : Distribution of species in drillhole 375 in order of first appearance

"Palynology of Ohai Coalfield, Southland."

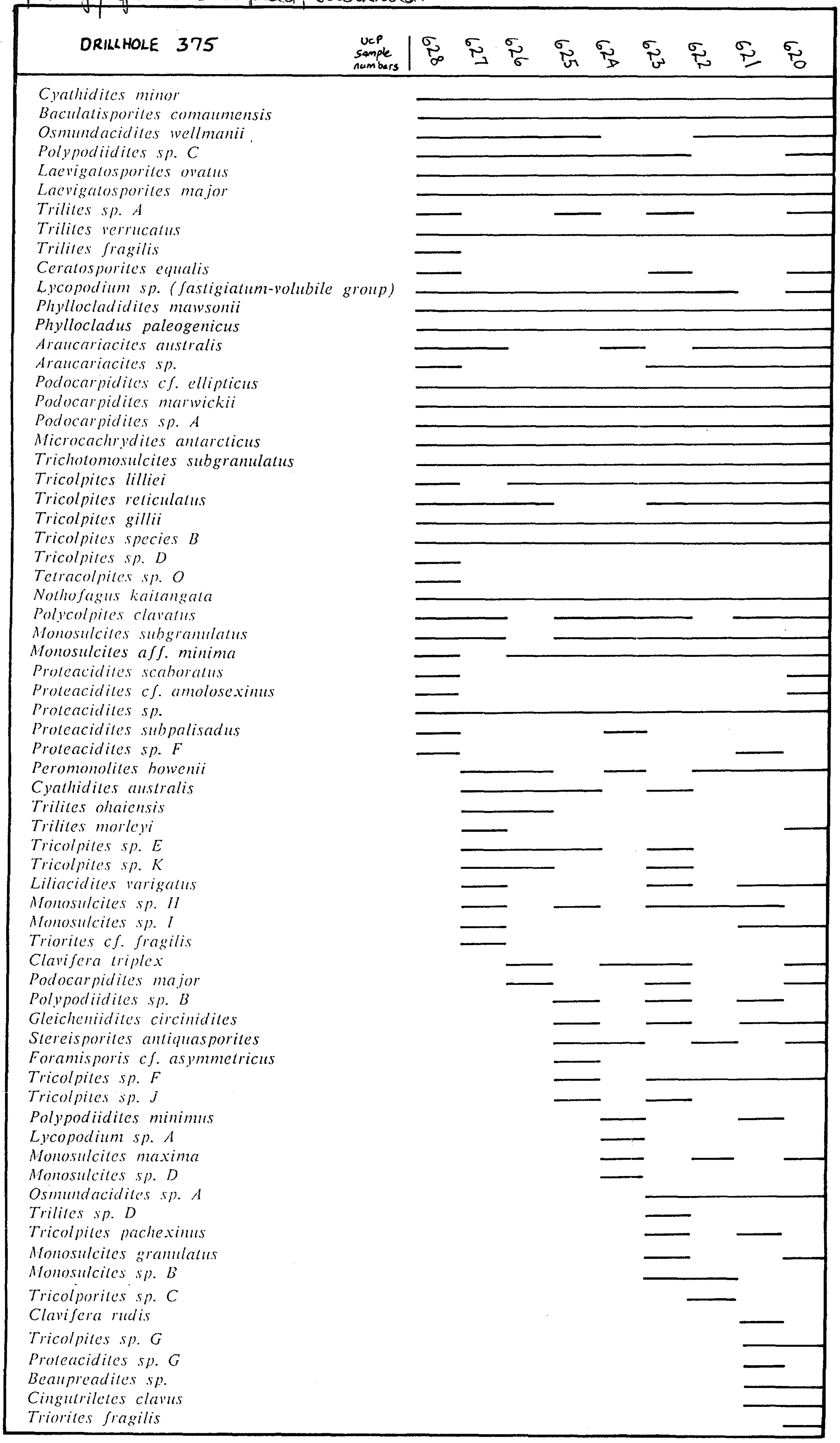


diagram to accompany thesis by M.C. Warnes "Palynology of Ohai Coalfield, Southland."

Figure 12i : Distribution of species in drillhole 384 in order of first appearance

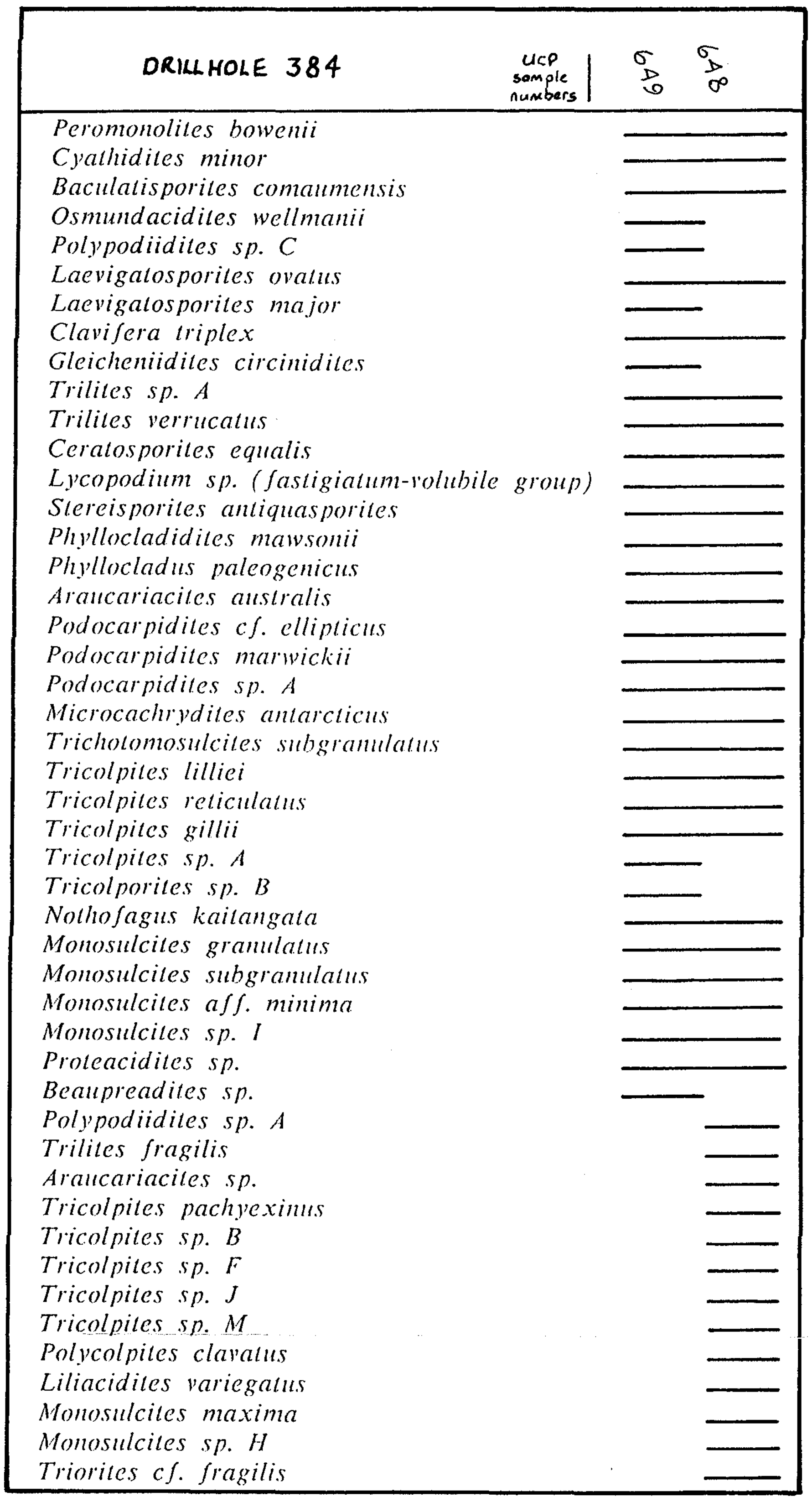


diagram to accompany thesis by M.C. Warnes "Palynology of Ohai Coalfield, Southland."

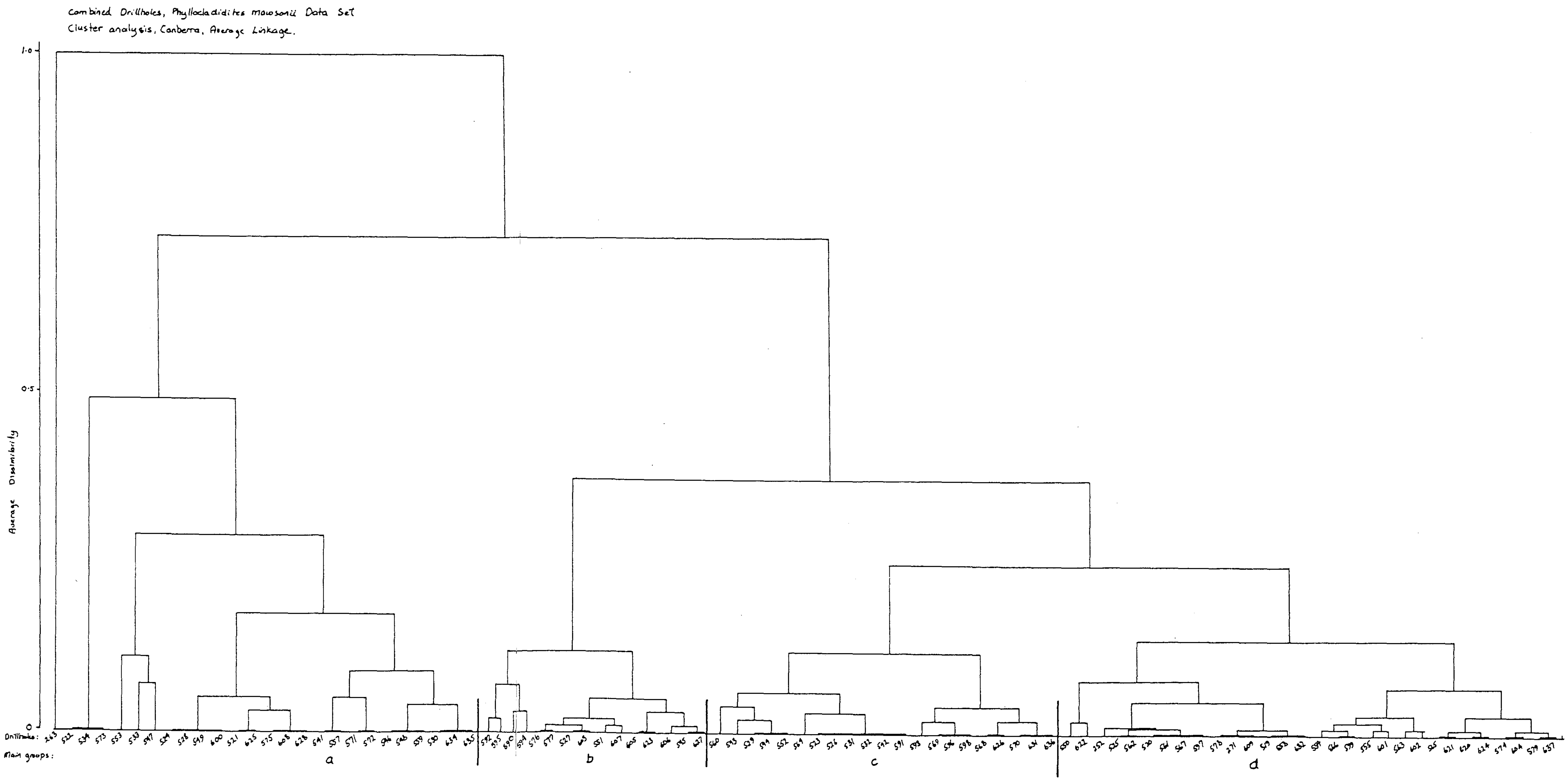


Figure 19 : MVSP dendrogram for *Phyllocladidites mawsonii* data set (combined drillholes)

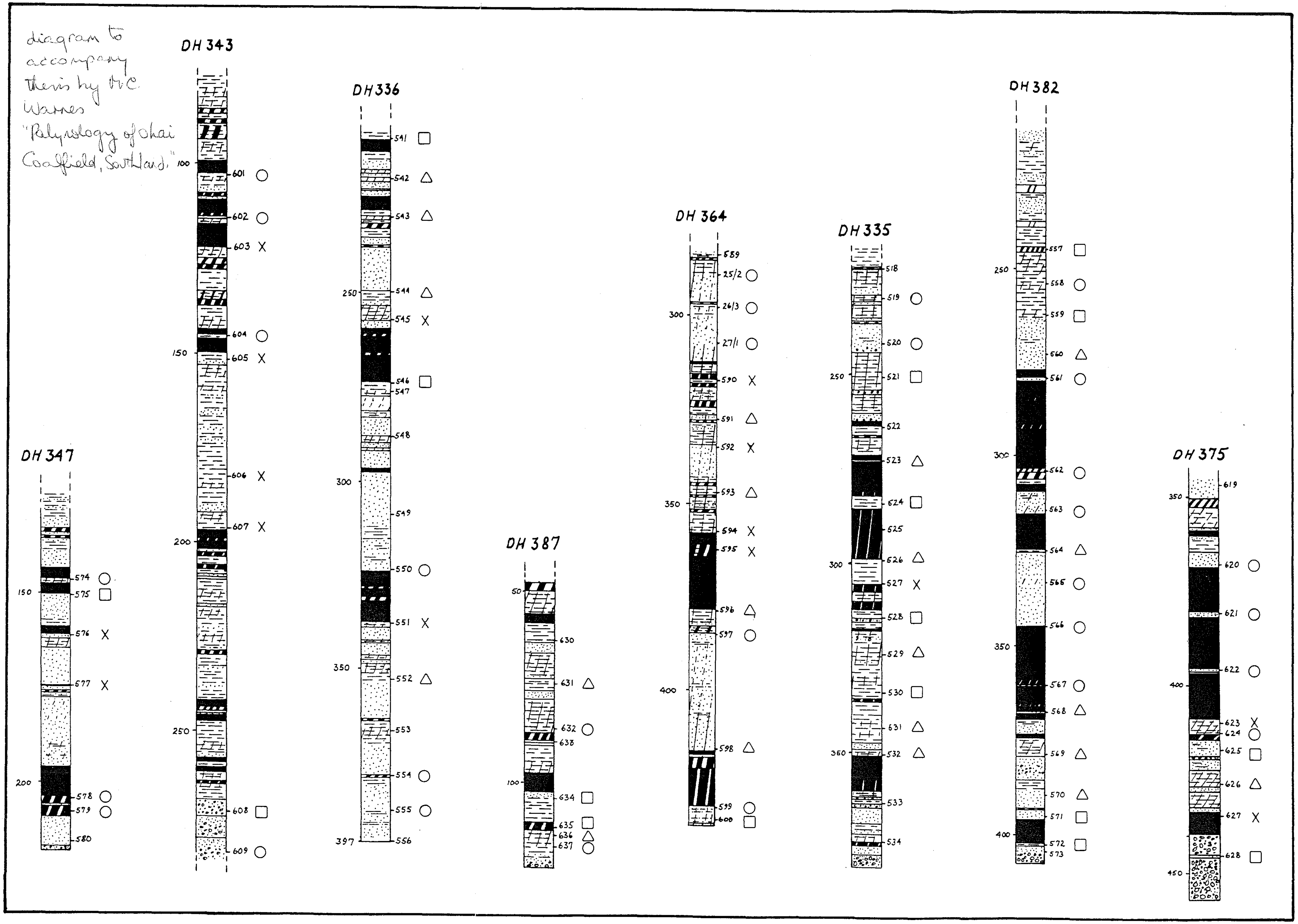


Figure 20 : Main groups defined by the MVSP cluster analysis of the *Phyllocladidites mawsonii* data set, for combined drillholes

diagram to accompany thesis by M. C. Walker "Palynology of Ohai Coalfield, Southland"

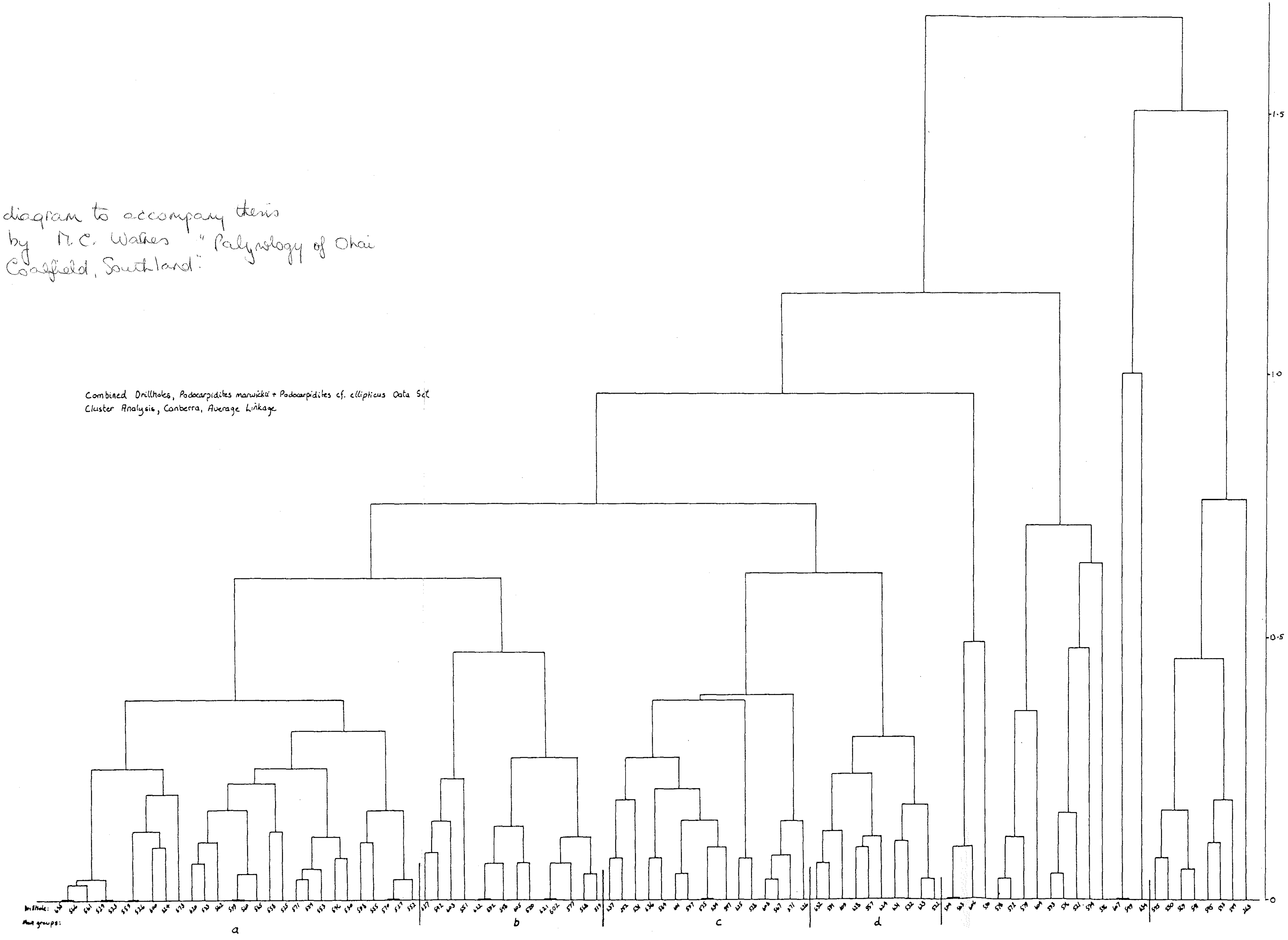


Figure 21 : MVSP dendrogram for *Podocarpidites cf. ellipticus* and *Podocarpidites marwickii* data set (combined drillholes)

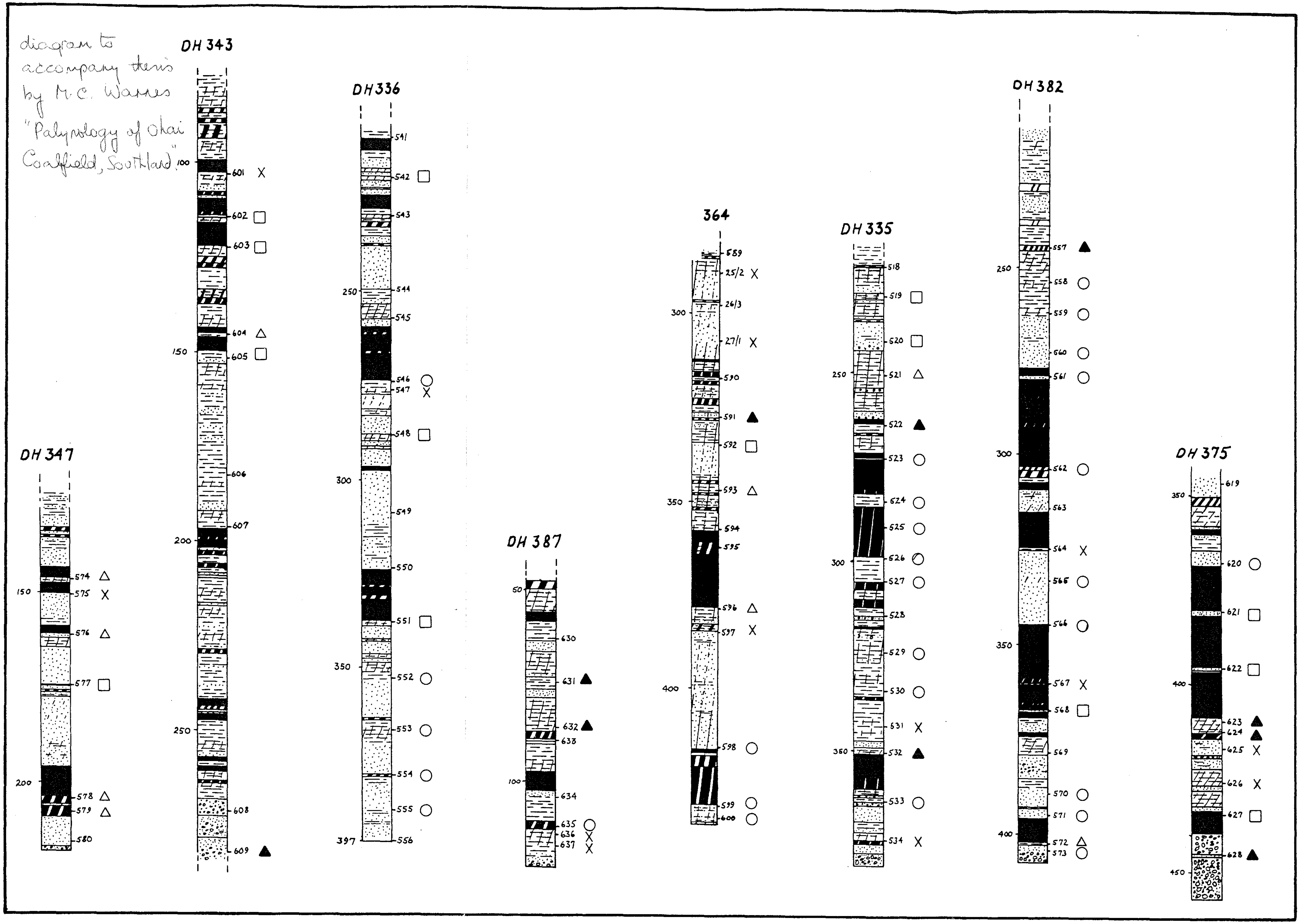


Figure 22 : Main groups defined by the MVSP cluster analysis of the *Podocarpidites cf. ellipticus* and *Podocarpidites marwickii* data set, over combined drillholes

diagram to accompany thesis by M. C. Warnes, "Palynology of Ohai Coalfield, Southland".

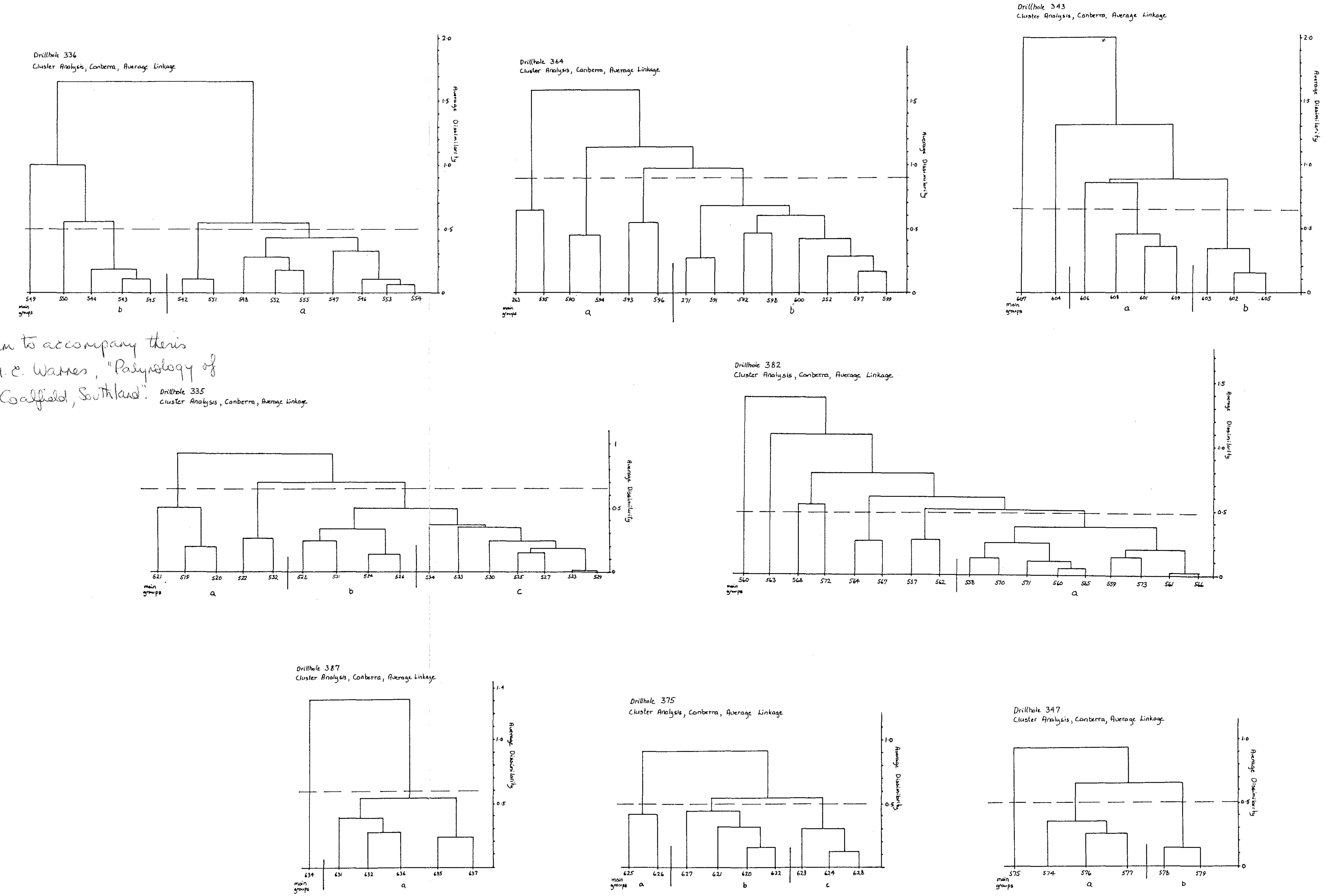


Figure 23 : MVSP dendrograms for the *Podocarpidites cf. ellipticus* *Podocarpidites marwickii* data set for individual drillholes

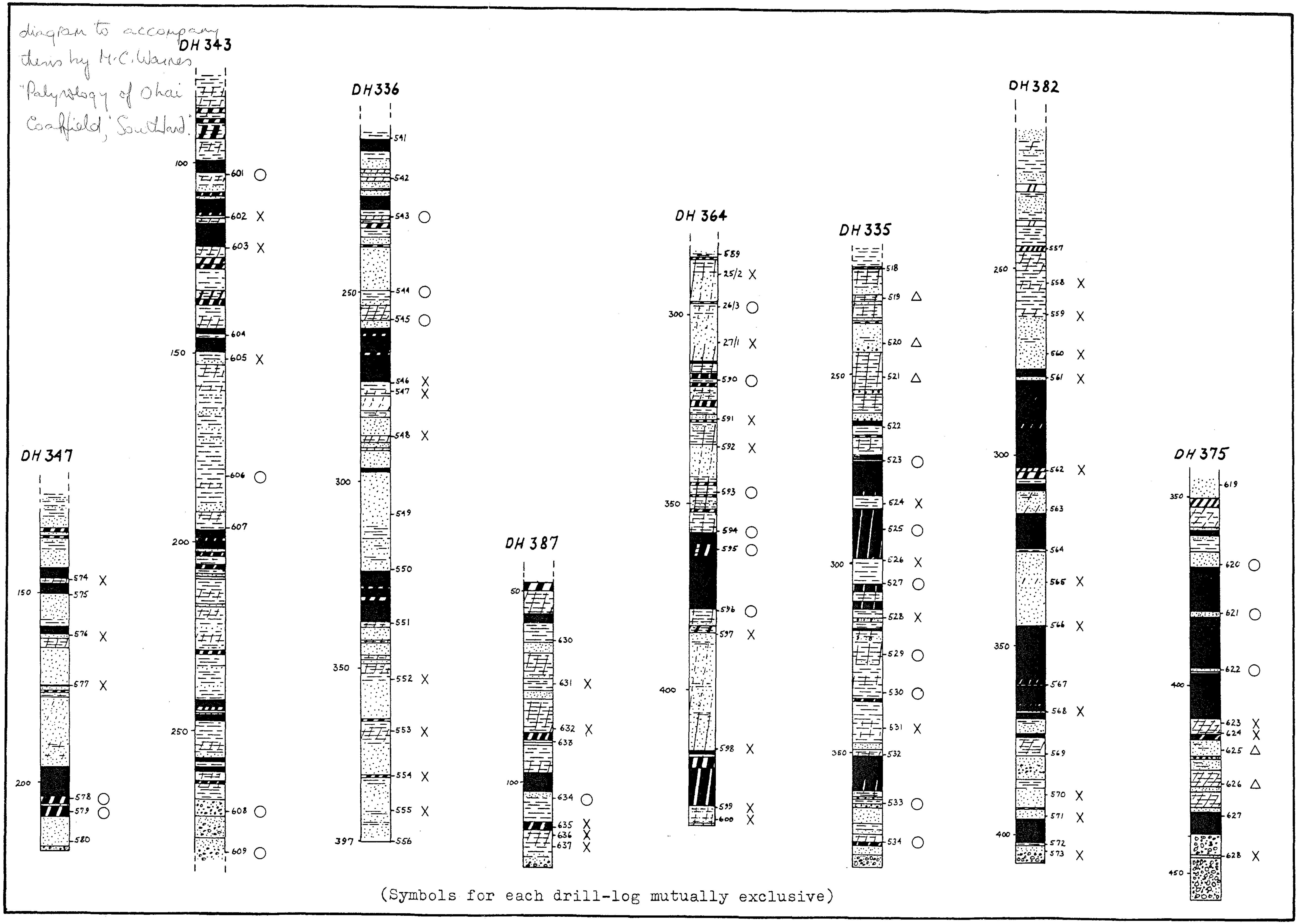


Figure 24 : Main groups defined by the MVSP cluster analysis of the *Podocarpidites cf. ellipticus* and *Podocarpidites marwickii* data set for individual drillholes

diagram to accompany thesis by M.C. Warnes
"Palynology of Ohai Coalfield, Southland."

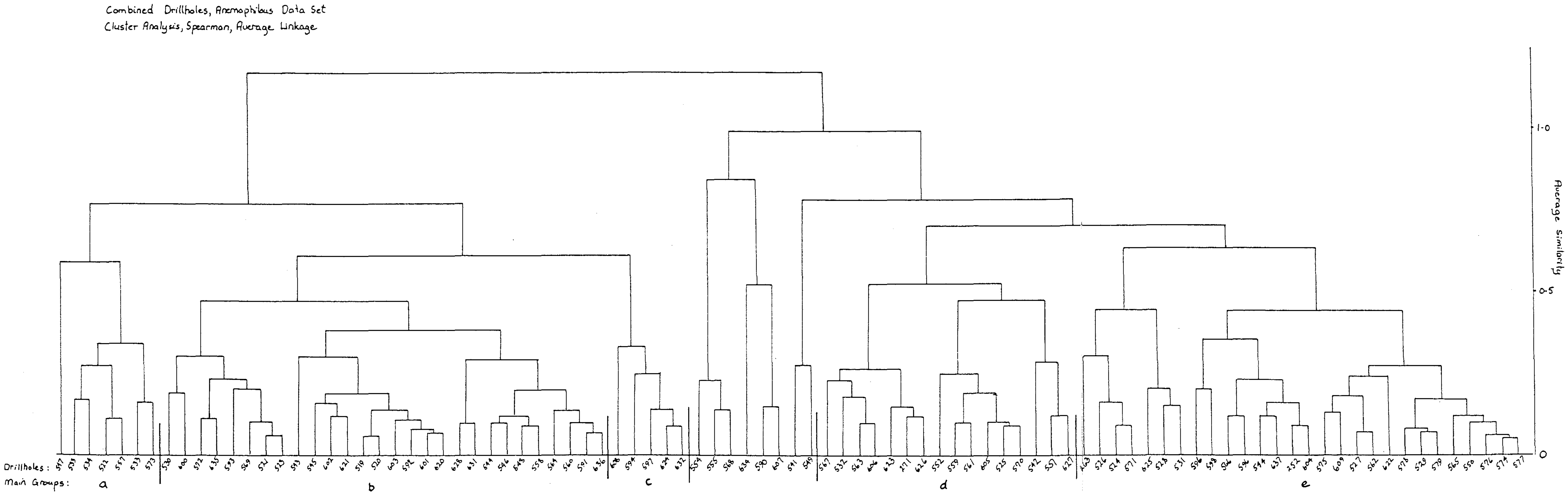


Figure 25 : MVSP dendrogram for Anemophilous data set, over combined drillholes

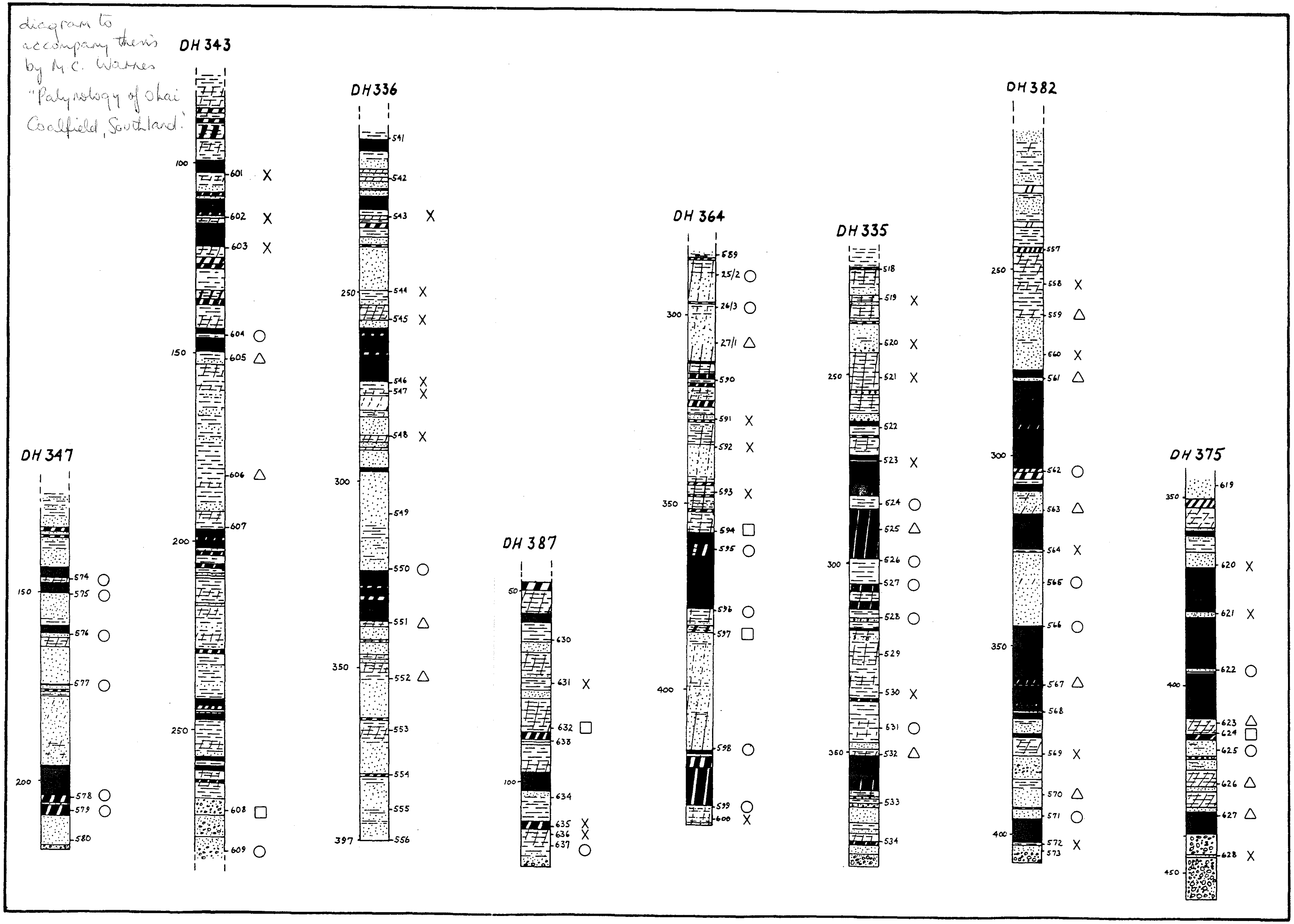


Figure 26 : Main groups defined by the MVSP cluster analysis of the Anemophilous data set for combined drillholes

diagram to accompany thesis by M. C. Warnes "Palynology of Ohai Coalfield, Southland."

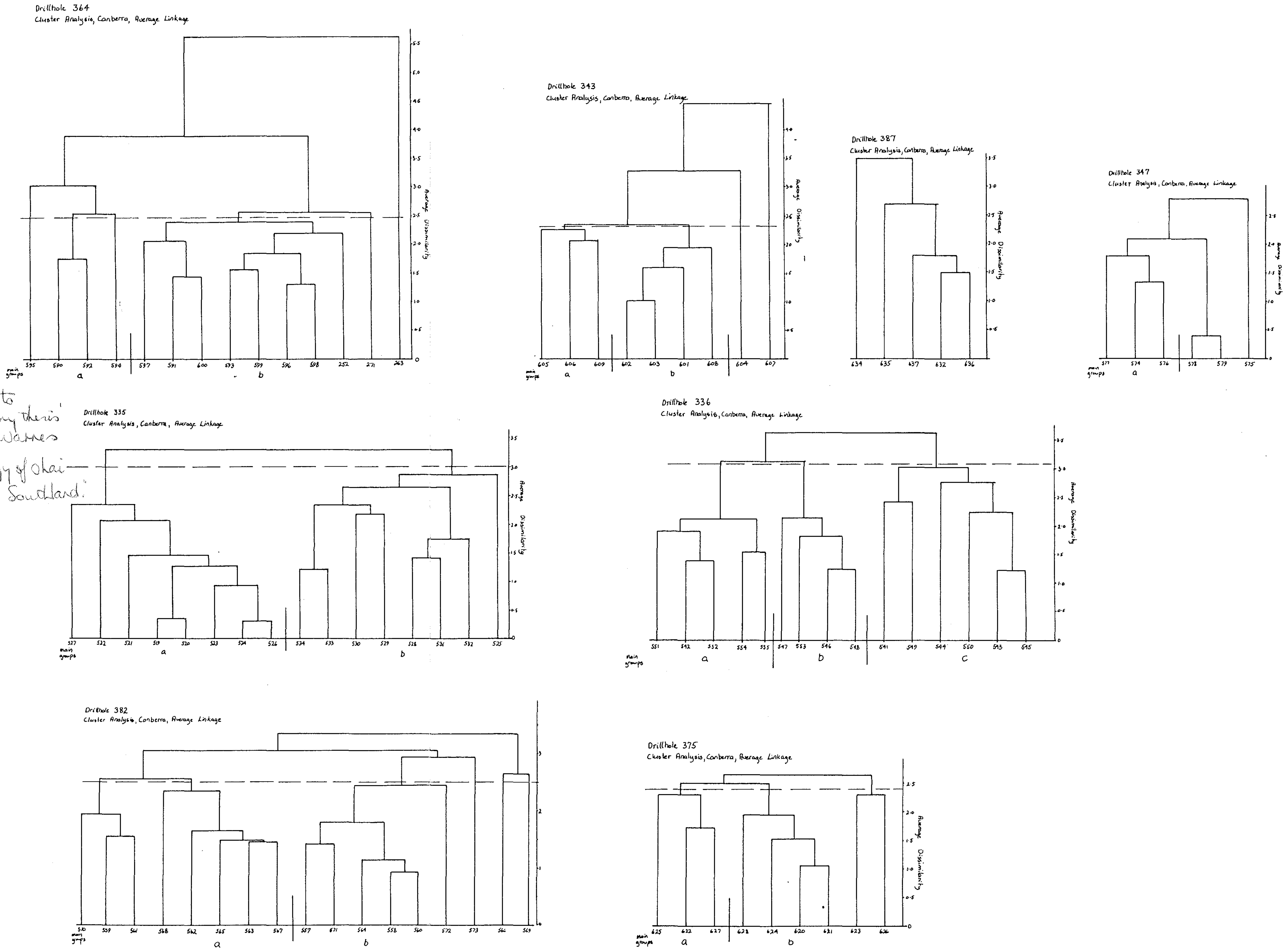


Figure 27 : MVSP dendrograms for the Anemophilous data set for individual drillholes

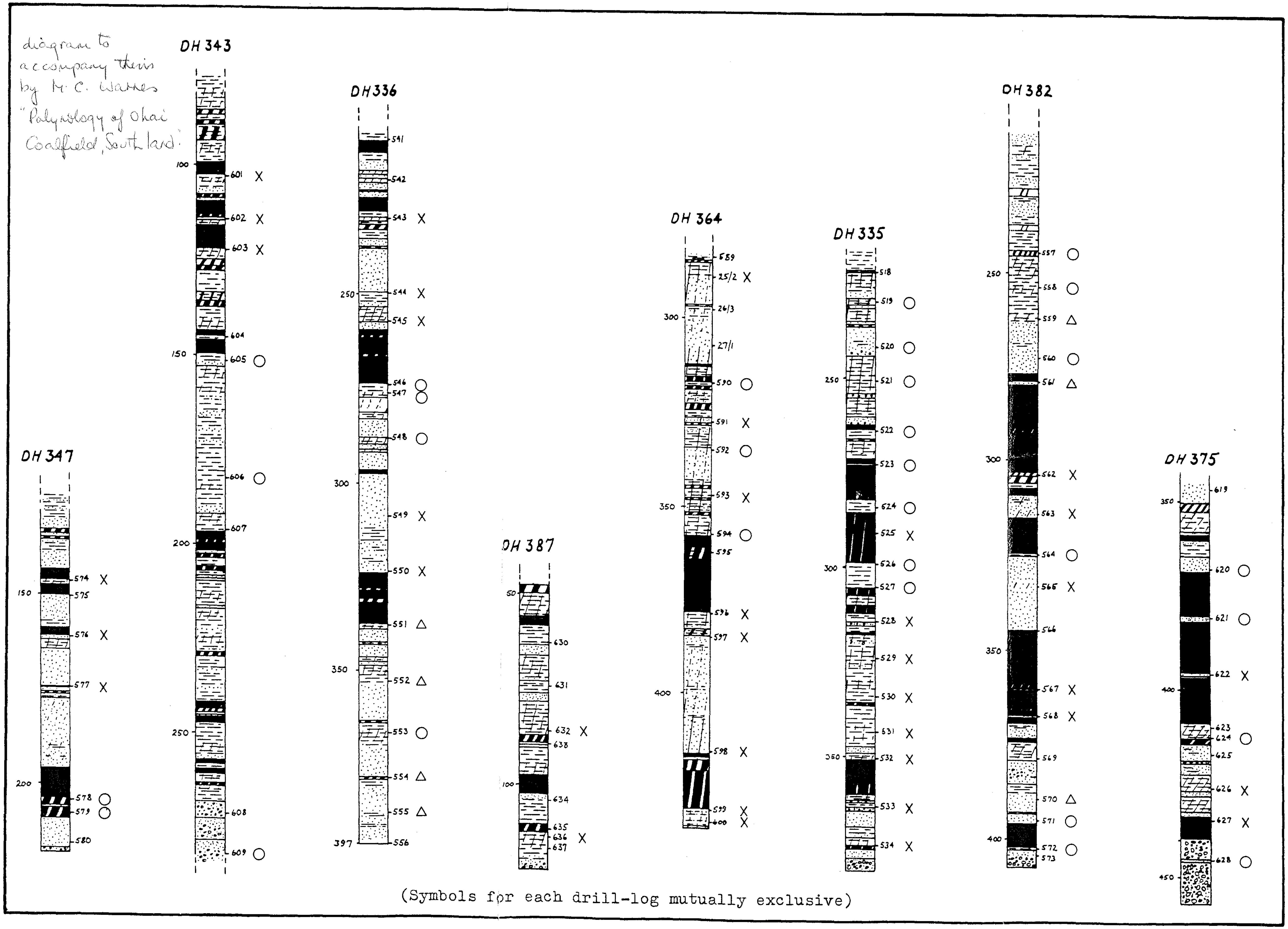
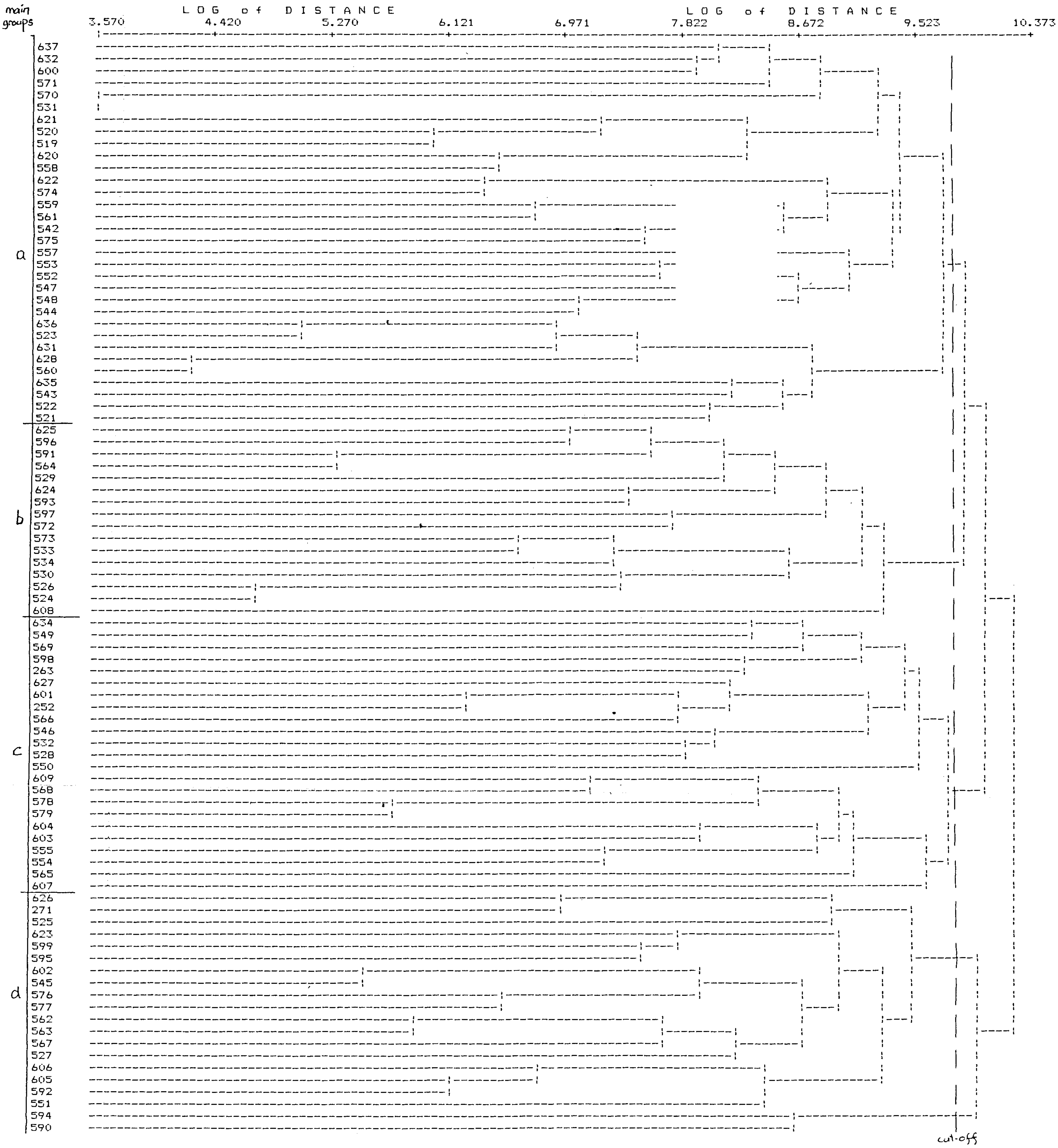


Figure 28 : Main groups defined by the MVSP cluster analysis of Anemophilous data for individual drillholes

Combined Drillholes, Pollen Sum 1 data, PC-ORD analysis.

CLUSTER ANALYSIS, EUCLIDEAN DISTANCE WARD'S METHOD

Percent chaining = 2.62



finished, normal exit.

Figure 29 : PC-ORD dendrogram for Pollen Sum 1 data set for all drillholes combined

diagram to accompany thesis by M.C. Warner "Palynology of Ohai Coalfield, Southland" diagram to accompany thesis by M.D. Warnes "Palynology of Ohai Coalfield, Southland."

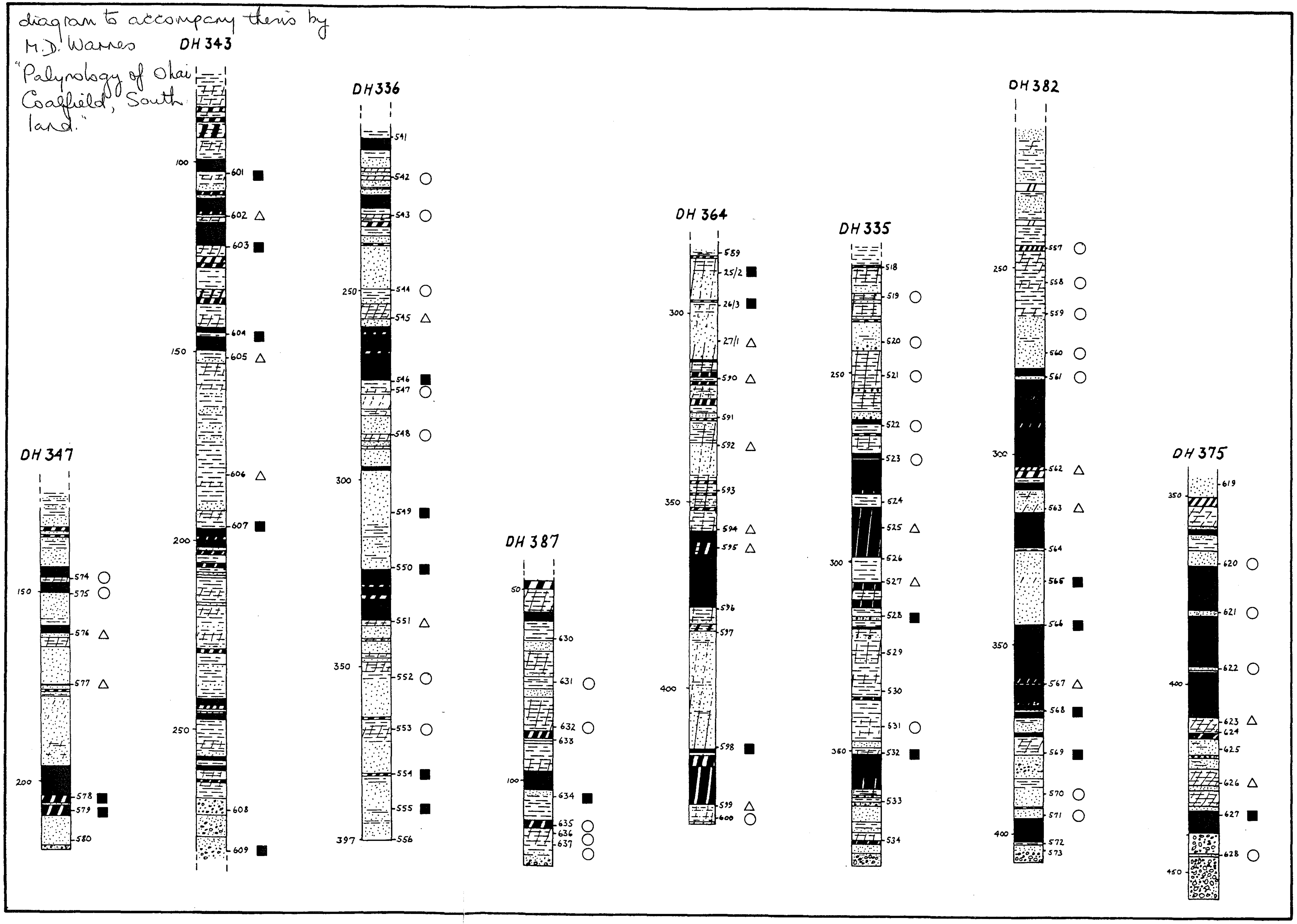


Figure 30 : Main groups defined by the PC-ORD cluster analysis of Pollen Sum 1 data over combined drillholes

diagram to accompany thesis by M.J. Warnes "Palynology of Ohai Coalfield, Southland."

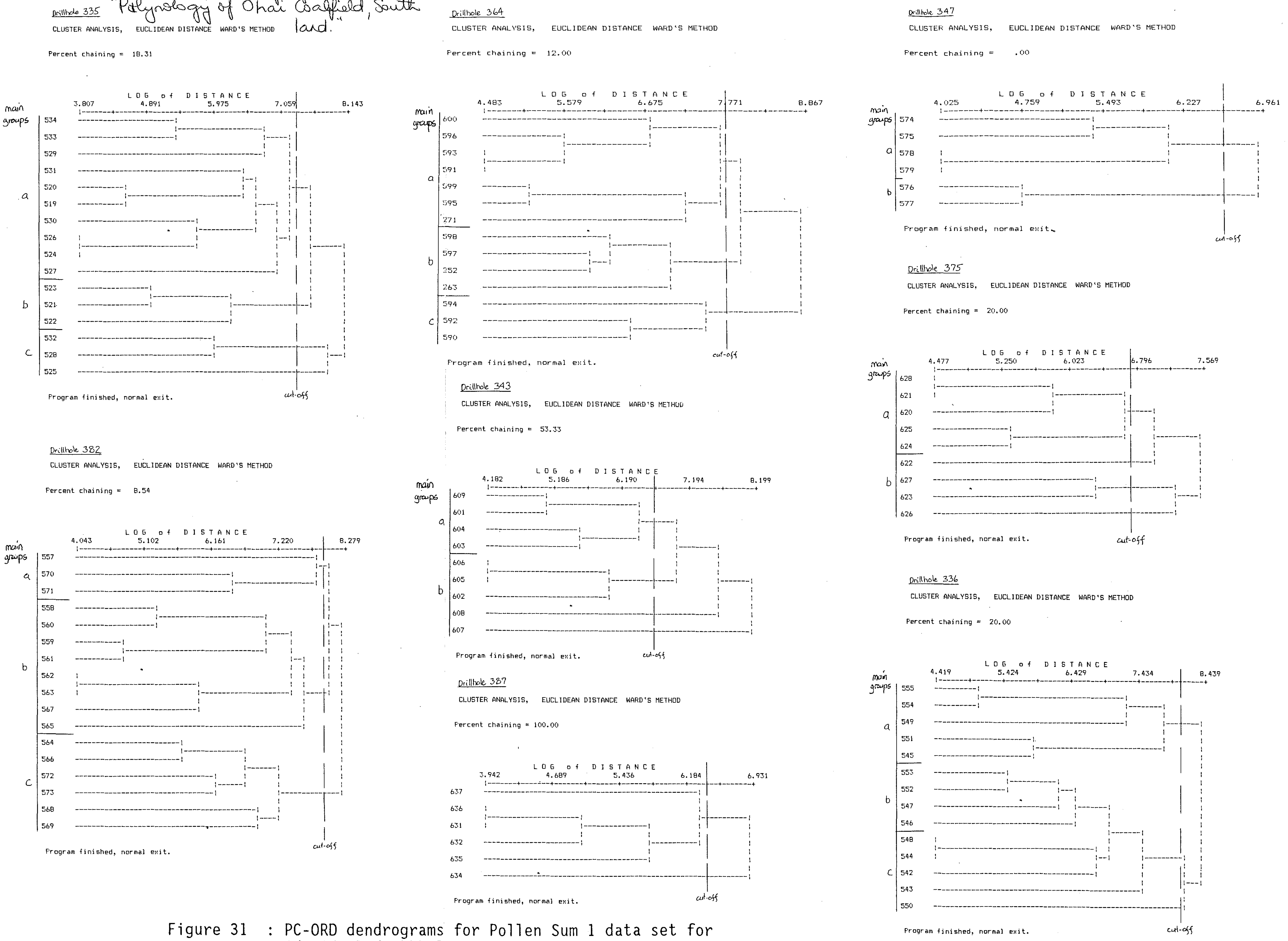


Figure 31 : PC-ORD dendrograms for Pollen Sum 1 data set for idividual drillholes

diagram to accompany thesis by M.D. Warnes "Palynology of Ohai Coalfield, Southland."

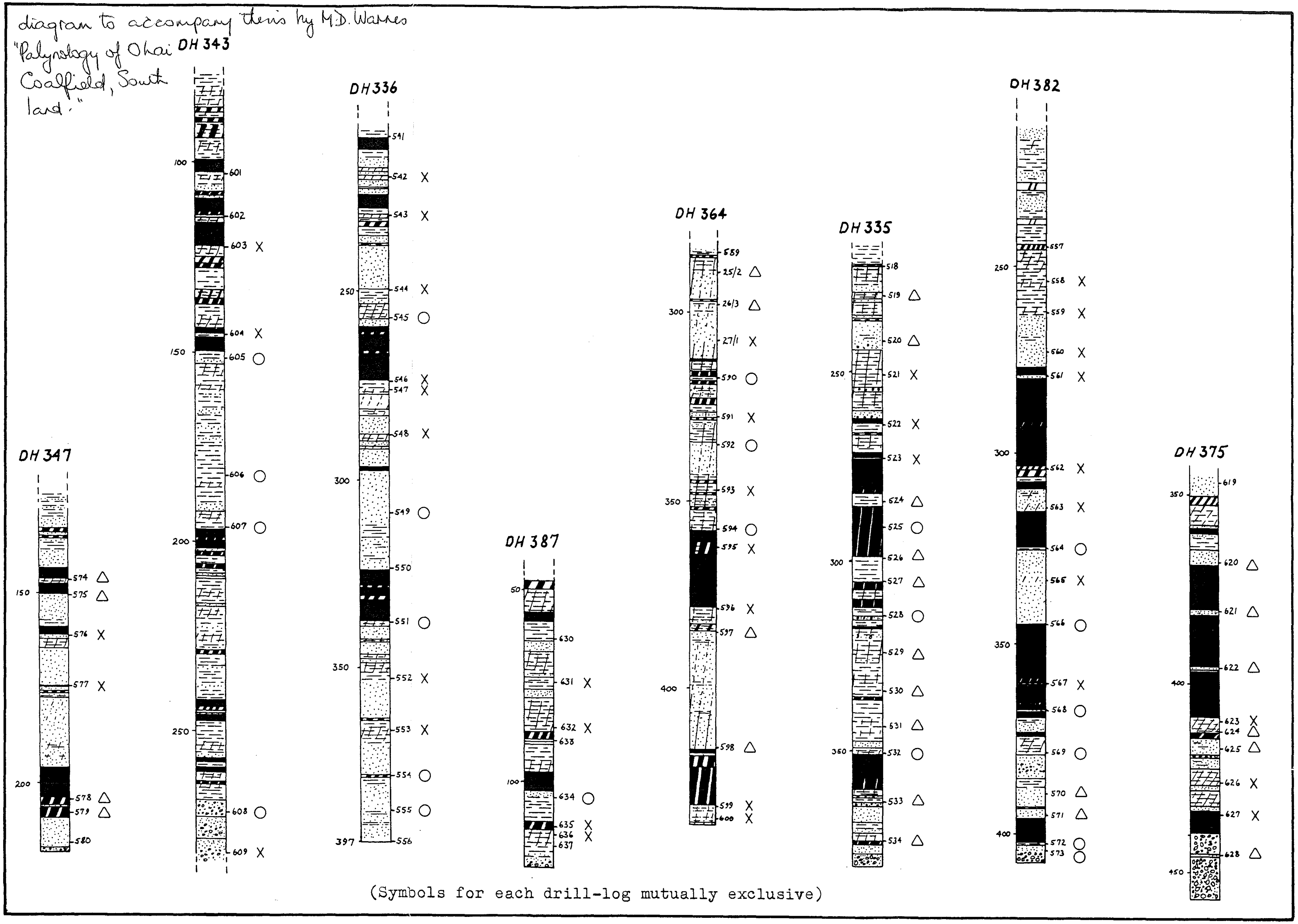


Figure 32 : Main groups defined by the PC-ORD cluster analysis of Pollen Sum 1 for individual drillholes

diagram to accompany thesis by M. D. Warnes
"Palynology of Ohai Coalfield, Southland."

Figure 33a : Ratio of *Phyllocladidites mawsonii* to total gymnosperms calculated for each drillhole

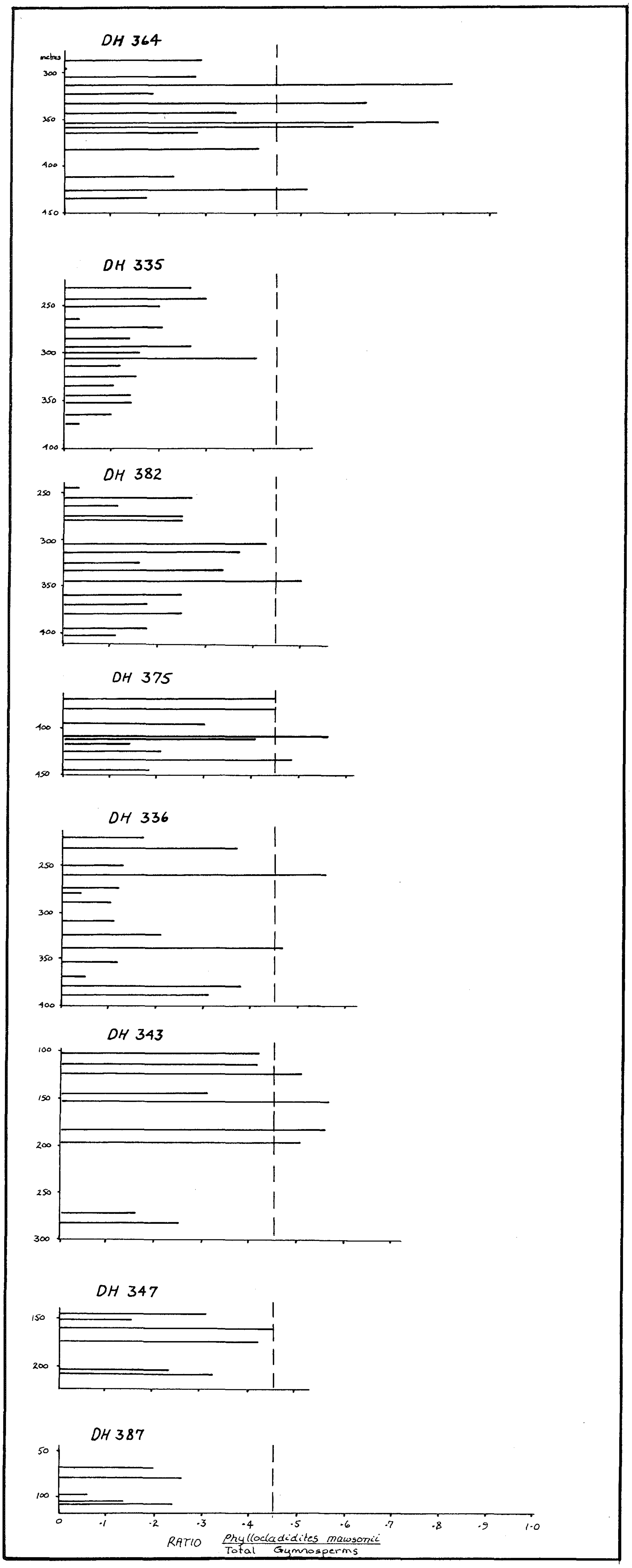


diagram to accompany thesis by M. D. Warnes "Palynology of Ohai Coalfield, Southland".

Figure 33b : Ratio of *Microcachrydites antarcticus* to total gymnosperms calculated for each drillhole

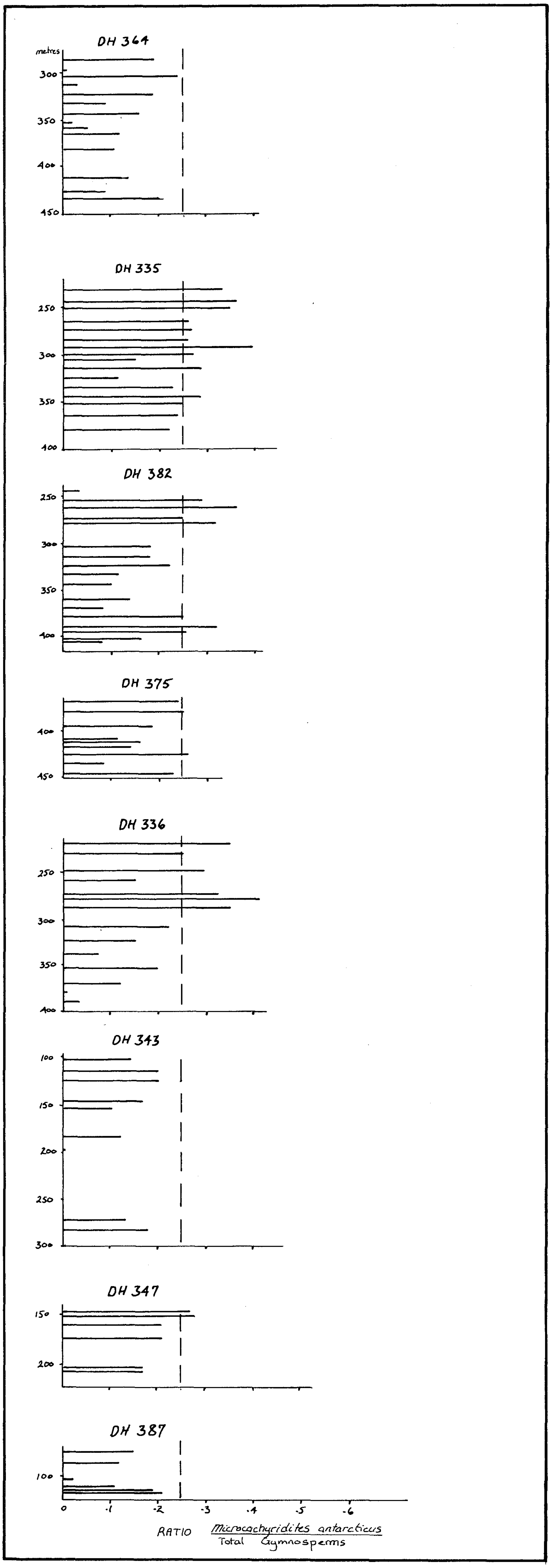


diagram to accompany thesis by Malcolm D. Warnes
"Palynology of Ohai Coalfield, Southland"

Figure 33c : Ratio of *Tricolpites gillii* to total angiosperms calculated for each drillhole

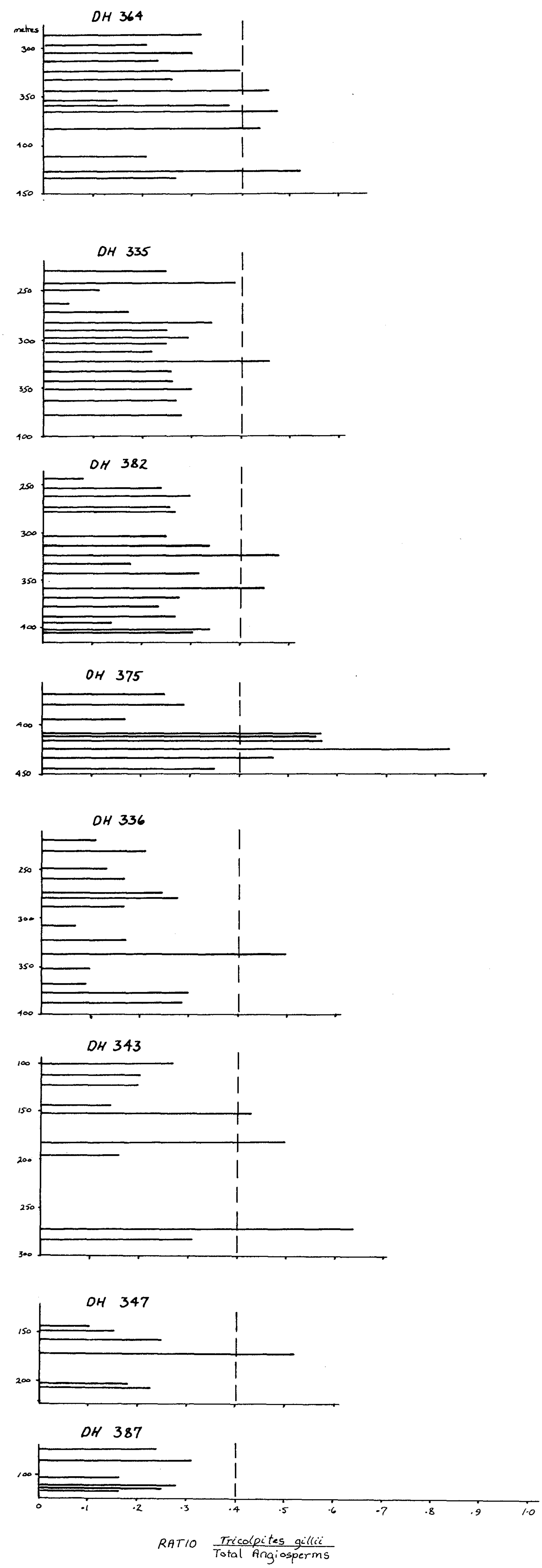


Figure 33d : Ratio of *Nothofagus kaitangata* to total angiosperms calculated for each drillhole